The Colorado Quarterly

THE UNIVERSITY OF COLORADO

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The Inverse Square Law in Physics

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The evolution of life

DAVID HAWKINS

In the last decade there has occurred a revolution in biology. It is not the work of one man or the consequence of one idea. A number of lines of investigation have converged, and in their convergence a new pattern of thought has appeared. At the center of the pattern is an idea. To explain it I shall start outside the world of biology. The contrast between the living and the inert is so profound that it needs to be taken by stages.

A first step might be to fabricate a cube of metal and then give it to a physicist to investigate. It is a sort of trick, a practical joke. Here is a curious piece of metal; what could be found out about it in the physics laboratory? This is the trick: using standard evaporating techniques we deposit a layer of some metal on a smooth surface, ten atoms thick. This is followed by a layer of another metal, also ten atoms thick. Three metals are used to build up successive layers in this way, say copper, aluminum, and lead. The metals are built to a thickness of a centimeter, detached and machined to a cubic shape.

The rule followed is that after every ten atoms of thickness the metal being deposited is changed, but can then be either of the remaining two metals. Now there are about 32 essential typographical symbols in our fonts of type, disregarding capitals and a few other luxuries. In five layers of the cube, with two choices per layer, we have a total of $2^5 = 32$ choices. Each of these choices is assigned to a typographic symbol, making a code. Building the metal to a thickness of one centimeter leaves room for about 3,000,000 layers or, at six letters per word and five layers per letter, 100,000 words. The physicist does not know it, but the cube we now give him is a copy of *Huckleberry Finn*.

What would the physicist do with such a cube to investigate its nature? Good and useful things, but not quite relevant. First there would be simple determinations, like density, thermal and electrical conductivity, and a micro-sample for the chemist. Then

there would be micrographs, showing some curious crystalline features, and X-ray diffraction studies, likewise a bit hard to interpret. But there would be nothing really extraordinary about the cube. When he was through the physicist might use it as a paperweight—but he would not have read *Huckleberry Finn*.

To compound the trick, imagine the cube built not in uniform layers but in tiny cubelets, ten atoms on a side. Three million volumes could now be encoded in a single layer and all the world's literature in a few of these. The whole cube could probably incorporate the literature of the galaxy.

But let us keep to the point of view of the physicist and insist on asking what, from a purely physical point of view, is so remarkable about this cube. What differentiates it physically from an ordinary metal cube? Well of course, it is literature, which the latter is not. What then—still from a physical point of view—is literature? Because we so keep things in compartments the question seems a strange one, which neither physicists nor literary critics are likely to think proper, and this is the point of raising it—it is the sort of question that suggests something of the new way of thought in biology. Living cells contain vast molecular structures whose nature is rather like that of a book and whose complexity is of the same order, or greater. The fonts of type are certain species of molecules which, like the type or like the metal layers of our cube, can be put together in arbitrary sequences and which provide a marvelous sort of biological code.

This code governs the chemical activity of the cell and, as a culmination, the final act of mitosis, of self-reproduction. But before becoming involved in the biology of reproduction, we should examine a simpler and more general question: How can *anything* reproduce itself, whether living or non-living? The question takes us into the new world of computing machines and logical automata. It is discussed in a now-classical paper by the late John von Neumann entitled "The General and Logical Theory of Automata" (1949). Von Neumann showed that the design of such a machine involves a crucial part, one rather like a book—not the metal cube or the printed volume, but a sizable roll of punched-paper or magnetic tape.

In his essay von Neumann considers an automatic machine

which is capable of assembling machine parts in a great variety of ways. Since this machine itself consists of machine parts connected together in a particular way, the self-duplicating machine seems possible, so that the race of such machines might perpetuate itself.

But there are objections. One might reason that it would take a machine of moderate complexity to build even a rather simple machine, and a very complicated one to build another only moderately complicated. Perhaps in general a given machine can be built only by one more complicated, and in that case the machine race is doomed to extinction. Von Neumann's analysis shows, however, that the essential trick is turned as soon as a machine is complex enough to contain a punched tape on which is recorded an adequate "description" of itself.

First, there must be a universe of machine parts from which, by selecting the proper parts, any machine of a certain kind can be built. The self-duplicating machine will now consist of certain recognizable components, to wit: 1) a universal assembly machine—"A"—capable of selecting parts from storage bins and putting them together in arbitrary combinations; 2) a punched tape, which contains the "description" of any particular machine and which, when fed into "A," causes the latter to select the proper parts in the proper sequence and join them properly; 3) a second machine—"B"—which, when fed a punched tape, duplicates it.

There exists, at the outset, a punched tape which gives the proper instructions for producing machines "A" and "B." When the tape is fed into machine "A," a new "A" is produced, and then a new "B." The tape is then fed into "B," and a new tape identical with itself is produced, which is fed to the new "A." One reproductive cycle is completed.

Now it is our contention that such a machine, while in no sense a living thing, indicates *something* essential about living things. Whatever else may be said about a living thing, this much may be said truly: A living thing is a system which contains within itself, encoded, information that will guide its own reproduction including the reproduction of that very information.

I shall be criticized for treating life mechanistically, in spite of the cautionary words above, or for describing machines animistically. Indeed I have already been talking animistically about

machines; "machine language" and "information" are examples. But such language has no metaphysical depth in the present context, and I propose to continue it. There is never a settled language for novelties, and if there is metaphysics in these analogies the discussion of it must wait.

One confusion, however, must be avoided. In saying that the Neumann machine contains a complete description of itself one only means that it contains a complete set of directions for reproducing itself. If self-reproduction requires 3,000,000 positions on the tape, each punched or not punched, the number of *possible* sequences of that length would be $2^{3,000,000}$. The tape "description" would cause the machine to select the right sequence out of this number. It could be read by a human properly equipped and would be about the same length as *Huckleberry Finn*.

It might take much more information than this to describe the Neumann machine in another sense, for the human designer of it in the first place or for the historian who discussed its subsequent career. But only one volume of this more complete description would be needed by the machine itself to reproduce itself. Such information may be called differential information, needed to distinguish one out of a large number of assembly sequences, and no more.

The analogy of the Neumann machine with the living cell is straightforward, although the style of architecture and the mode of operation are profoundly different. The punched tape corresponds to the chromosomes in the cell nucleus. The assembly machine and the tape-duplicator correspond to phases, relatively distinct, in the performance of the rest of the cell, the cytoplasm. The bin of parts is the surrounding nutrient of the cell, whose wall is engineered to accept certain molecules from the ambient fluid. In the cytoplasm at any time are molecules of many kinds, which can interact to form new molecules. Among them are energy-rich structures capable of driving reactions, to the products of which they transfer some of their energy. Among them also are rate-controlling molecules, enzymes whose variety and concentrations determine which reactions, of the enormous number possible, will predominate. These catalysts are like little assembly-machines, which bring things together in specific orientations,

facilitating associations and dissociations that would otherwise go much more slowly. And catalysts are catalyzed; the original catalyst is the set of chromosomes themselves. Like the tape of the Neumann machine, moreover, the chromosomes catalyze the production of molecular machinery which, in the end, duplicates them and starts a new cell on its career.

The genetic material, the catalyst of catalysts, exhibits one of the most characteristic architectural themes of biochemistry. Inorganic molecules and crystals are essentially three-dimensional structures; the characteristic biochemical big molecule, on the other hand, is a linear chain, a string when stretched out, but often coiled as a helix. This is the case with the material of which chromosomes are built, desoxyribose nucleic acid or DNA. Each molecule is a very long double chain like a twisted rope ladder with cross-rungs spaced closely together and connected by the two chains. Each of these cross-rungs consists of two links, one of a type called purine and the other called pyrimidine. In DNA there are two purines, A and A′, and two pyrimidines, B and B′. A forms a cross link only with B, and A′ only with B′, giving four distinct cross-links AB, BA, A′B′, and B′A′.

At this point the analogy of the metal cube and the punched tape comes into its own: The cross-links are code-symbols in a four-letter code, and in n successive rungs of the ladder 4^n messages can be coded. Spaced as closely as they are, a few hundred-millionths of a centimeter apart, there are a billion or so loci to be filled in the chromosomes of a single animal cell. Within these loci is written the book of life. In some way, which George Gamow and others have labored to decode, the sequence of cross-rungs in the DNA fibers guides, or acts as a template for, the fabrication of myriad enzymes. The enzymes in turn are linear arrays, this time composed of the twenty or so essential amino acids of which protein is built. They are abstracts from the parent catalyst, and they direct the chemistry of the cell. Current estimates place the number of these catalysts in the neighborhood of ten thousand for human cells, slightly smaller for other animal species. Each is the translation of some corresponding section along the chromosome fibers, and it is these sections which are called genes. If the

chromosomes are comparable to volumes of a great encyclopedia or formulary, the genes are the separate articles.

The structure of DNA is of still recent discovery, one made by J. D. Watson and F. H. C. Crick. Still more recent investigations support the conjecture that the all-important reproduction of the chromosome is a process in which it comes unzipped down the middle between each purine-pyrimidine pair. Each half is the unique complement of the other; each attracts, from the ambient fluid, the complementary purines and pyrimidines, and a new side "rope" forms. After chromosome division, cell division takes place.

Many of the small steps and some of the big ones in this process of cell-reproduction are only slightly understood, and there may still be big surprises. The general outline seems, however, to be secure. In terms of this outline it is possible to give a general and very abstract characterization of life. In doing so I shall have recourse to thermodynamic ideas long familiar to physicists and chemists.

Life depends upon a constant supply of energy, but not merely of energy, not for example of mere heat energy. In the context of constant temperature process (to which those of life belong) we define a certain *free energy,* which means that portion of the energy of a system available to do work. The total energy of the system is divided between free energy and heat. At constant temperatures heat is proportional to entropy, so that of two systems at the same temperature and with the same total energy, the one with the lower entropy has the greater free energy.

The concept of entropy is a rather subtle one to understand in all of its ramifications. It is a measure of the disorder of a system defined, roughly, in terms of the number of alternative detailed states the system may be in under given conditions. When these conditions determine the state of the system completely its entropy is zero. On the other hand the entropy of a system is maximum when all possible states are equally probable. Thus in the case of a perfect crystal composed of identical atoms at absolute zero temperature, the entropy of the crystal would be zero. The entropy of a mass of gas under standard conditions is positive: it measures how much, from a knowledge of these conditions, one

cannot say about the positions and motions of the individual molecules.

A type of entropy of importance in biology is what may be called entropy of arrangement. It applies to things that have some sort of rigid structure, and refers only to that part of entropy associated with structure. A diamond crystal has a lower entropy of arrangement than an equal mass of diamond dust. A piece of iron magnetized has a lower entropy than the same iron with its atoms randomly disoriented.

The negative entropy of a cell is the abstract measure of the planfulness of its molecules and the orderliness of its functioning. Patterns of molecular arrangement, encoded in the DNA, are transferred repeatedly to constituents of the cell. Being formed to a pattern rather than assembled by chance, the molecules of each species within the cell have a very low entropy of arrangement. When the supply of them has increased sufficiently and the DNA duplicates itself as well, the two daughter cells resulting from fission are in essence identical twins; barring accidental variations or mutations, their DNA and their other constituents are replicas. But this means that the entropy of arrangement, in the two cells considered together, is no greater than that of either one alone; and the specific entropy, the entropy per cell, is half as great as it was before.

The lowering of entropy in such systems corresponds, however, to a greater free energy, a greater capacity to do work. The second law of thermodynamics asserts that such an increase of free energy cannot come about spontaneously; it can come about only if there has been a loss of some other kind of free energy, at least as great. The free energy that is lost is chemical energy, constantly renewed from the food-supply and constantly expended in the work of self-duplication. It is lost only in a relative sense. Part of it is stored in the chemical bonds of the cell-constituents; part of it is truly lost, converted to heat without any compensating reduction of entropy; the part we are interested in is not lost. For by the ordering it has brought about, it can be recovered again to do work.

The quantities involved in this thermodynamic bookkeeping have not all been well-measured, but the upshot of rough estimations is that a sizeable part of the power input of living matter is

accounted for by the work necessary in duplication of structure and in the reduction of entropy which this duplication involves.

It might indeed be found that the total power supply of the cell is *less* than what is needed to produce this increment of order. In that case we would be faced with the possibility sometimes entertained by vitalists, that life is a standing violation of the second law of thermodynamics. Probably, however, the free energy of reproduction is more like a tenth or a hundredth of the total available. Whatever the fraction, it is a relatively large proportion of the total, and relatively enormous compared to the corresponding energy in any non-living system which could fission or in some other way increase the number of its parts. For most such systems (including certainly the plutonium atom) the free energy in question is negative, for the change involves a liberation of heat.

Even for the Neumann machine the free energy of reproduction, while positive, would be utterly negligible in proportion to that needed for the gross operaton of the machine. For this free energy is proportional only to the amount of order created. If a Neumann machine weighing tons and consuming kilowatts of power managed to be anywhere nearly as complex as a cell—if its tape had to be as many words long as the DNA—its free energy of reproduction would be no greater than that of the tiny cell. Thus it would seem that life has to be chemical in its operation and microscopic in its organization. Only in such a structure is it possible to operate without the creak and grind of energy-wasting macroscopic processes.

A living system is a system which contains a complete differential description of itself and in which the free energy of reproduction is comparable to the total free energy. Only in living matter, so far as we know, is this proportion large; elsewhere in nature it is utterly trivial.

The distinction between the living and the non-living is still incomplete. It is sufficient, however, to reveal a separation, a gap in nature. On the scale labeled "specific free energy of reproduction," living things cluster in the region of one tenth, 10^{-1}. Non-living things range from near zero—perhaps 10^{-20}—into the negative region of the scale. And there is nothing in between. The theory of evolution implies, however, that the gap diminishes

toward the past. Until recently the theory of evolution started with the hypothesis of single-cell life and left its antecedents to speculation. But a single cell is already so complex that colonies, organisms, and even man are only slightly more so, on the thermodynamic scale. To close the gap, if we can, we must go into the dim pre-Cambrian era. In that era, unfortunately, the fossil record is lost.

Let us start, instead, with a second look at the Neumann machine. Its self-reproduction is completely controlled, so that the daughter machine is a replica of the parent. If the generations are not infinite there must have been a first, and the first must have come about differently. One is faced with the problem of creation. Von Neumann suggested that in the process of copying tapes, little errors might occur, the analogues of genetic mutations. These could be lethal, so that the daughter machine could not reproduce. In other cases the mutant machines might be viable, and natural selection could operate.

Clearly, however, such a process of mutation and selection will not account for the origin of *Mechanicus Neumannensis*. For *any* self-reproducing machine must have a considerable minimum complexity; this gap must be jumped in some other way. It was in a comparable condition that Darwin, apart from a suggestive remark or two, left the origin of life. Like the simplest Neumann machine, a living cell cannot evolve and become differentiated into species until it is already complicated enough to be capable of self-reproduction.

The answer in the case of the Neumann machine is evident. On every such machine there is a small brass plate, reproduced along with everything else and saying: *Neumann me fieri fecit*. This machine is an offshoot of a new kind from the previous evolutionary tree, a twig from the branch of Man and symbiotic with him. Its pedigree does not begin in the twentieth century but billions of years ago in the tide pools of the pre-Cambrian. It is not alive; but it is complex enough in the sense that life is complex, that it can hardly exist against a less ancient and distinguished background.

Aristotle was right; order can come only from order. *Mechanicus Neumannensis* can only be explained as the product of an

external cause, as Aristotle explained the bed and the house. Perhaps man's earliest living ancestor cannot be explained except similarly, as a miracle.

There are two kinds of miracles, according as they violate the first law of thermodynamics, the energy conservation law, or the second law. The origin of life may seem to be in violation of the second law, because the chance assembly of matter into a self-reproducing cell appears so improbable that no sober scientific logic could distinguish it from the impossible. The second law says (just as Aristotle did) that the entropy of an isolated system will not spontaneously decrease, and that is just what the appearance of life would seem to involve.

In fact the argument against a spontaneous appearance of the Neumann machine would seem to hold of life *a fortiori,* for as we have said the free energy of reproduction is much greater per pound of living matter than per pound of the Neumann machine; life is more highly organized than the machine.

But the argument works both ways. The Neumann machine is a probable sort of thing in the industrial world of the twentieth century. Do we know that life was not a probable sort of thing, to appear on the Earth as it existed two or three billion years ago? At temperatures probably not much different from those that prevail today, in an atmosphere containing things like ammonia and methane and no oxygen, sunlight and its subsidiaries such as lightning would produce energy-rich carbon compounds of considerable complexity, for example the amino acids. This has been demonstrated repeatedly. In such a milieu there would occur a complex carbon-dominated molecular evolution. It was argued by Oparin and others that the main error in most previous discussion of the origin of life was the unconscious assumption that the environment-to-be was similar to the present inorganic environment. On the contrary one must assume a previous chemical evolution over periods of great length, some of whose molecular products are just the basic chemicals of life today. As applied to that early period the term "non-living" would be as inappropriate as the term "living," for by the former we tend to mean the simple environment of today. Life and its environment have evolved together; the old environment was, quite literally, eaten up.

Under such conditions of chemical environment, moreover, one may postulate a relatively simple mechanism that is self-reproducing, and it would consist of a double chain structurally just like the genetic material of life, the DNA. Random DNA, that in which the enzyme code has been scrambled, has been made in the laboratory. We may take this as a model for the first self-reproducing molecules. They come apart and each part picks up its complement, bit by bit, from the environment; in place of one such molecule, there now are two. And soon there will be four, eight, and so on until the "food" supply becomes a limiting factor.

From a thermodynamic point of view this self-reproducing molecule is the absolutely basic turn of events. Here is a molecule of two parts bracketed, (AB). Each part uniquely defines the other, and therefore their total entropy is no greater than either one considered by itself. They come apart and each, in a process with many individual steps, rebuilds a complement. As this process repeats, the orderliness of a region of the universe increases, its entropy of arrangement decreases. Free energy flows in, heat flows out, and there is left behind an increment of order. The principle of the self-reproducing molecule is a new law of thermodynamics, one whose formulation marks the confluence of two great nineteenth century traditions, the traditions of thermodynamics and evolution, of Clark Maxwell and Charles Darwin.

The self-reproducing molecule already removes one thorny problem about origins. Living things did not come first and only later acquire the capacity to reproduce. This would indeed be miraculous, for biological "learning," spontaneous variation and natural selection, already presuppose reproduction. Living things did not learn to reproduce themselves; rather, things that reproduced themselves learned to live.

A self-reproducing molecule, even though internally inert and externally naked, is subject to the Darwinian principle of variation and selection. At the stage when such reproduction became limited by scarcity of raw materials, some DNA-like molecule suffered a chance mutation of order among the cross-links of the chain, and this region of its structure became the first gene; it catalyzed the formation of new molecules needed for its own

reproduction. The molecule tapped a previously undepleted reservoir, and its descendants flourished.

But I would not call such a system "life." Like the modern virus, it was internally inert. If the term "life" is to be used at this stage, it should be applied to the whole tide-pool or perhaps the whole ocean. There was as yet no differentiation between organism and environment. Life appeared, rather, when the self-reproducing molecule and the reactions which it catalyzed—by then a whole system of them—became encapsulated in a membrane which gave to its possessor a new advantage. It increased the concentration of material, and therefore the reaction-rates of the processes involved in reproduction.

The description of such membranes involves us in a new application of thermodynamic ideas. The semi-permeable membrane, which admits one molecule and excludes another, is an informed membrane; it exists in a specific relationship of lowered entropy with respect to the environment. The cell is discriminating, selective; it sets itself over against its environment, and is not merely an inert element in an ensemble. It is a microcosm that maintains commerce with the world and is not just kicked around. It is, I would say, alive.

In modern organisms there are some very long reaction-chains, from simple raw materials to complex "consumer goods." In the new framework of thought these chains evolved backward, from end-product to present-day raw materials. At first everything was provided from the previous stage of purely chemical development, a sort of aquatic Garden of Eden. As in the social evolution of economic systems, more steps of fabrication appeared and raw materials became simpler in structure. Man may, before long, learn to produce his own food supply independently of the green plants. Life as a whole became independent of the earlier chemical stage of evolution when these same green plants, the photosynthesizers, appeared.

This conception of backward development takes care, in principle, of another weighty argument against evolution. The long biochemical reaction-chains need many enzymes, implying many evolutionary steps, before the useful end-product appears. Since the biological utility of the whole chain depends upon the ap-

pearance of the last member, there would have been no evolutionary advantage to the intermediate steps and they would not have evolved. N. H. Horowitz has pointed out, however, that in backward biochemical evolution, from product to raw material, every step has utility; for every step taps a new source of supply.

Is this account of the origin of life science, or is it mere speculation? A cautious answer, I believe, is that it is not *mere* speculation. Some of the guide-lines are well-established, but the historical account itself is not. A better question is, can it be tested and is it open to continuing research? The geological record, this far back, is pretty completely erased, although as Aaron Novick suggested it is not inconceivable that ancient DNA might one day be found in rocks and, even, revitalized.

But there is another source of evidence, as yet largely unanalyzed. The backward evolution of chemical reaction-chains means that such a chain, and the genetic code that controls it, is itself an historical record. As gross comparative anatomy permits the reconstruction of more recent evolution, so comparative biochemistry and the micro-anatomy of genes and enzymes will extend the range. We and our biological contemporaries are all of us history books. Naturalists have marveled at the inventiveness of life—the craftsmanship of the spider, the husbandry of the ant, or the vector-language of the bee. But here surely is a marvel beyond all others, that life has kept, through a billion years, the written chronicle of its own career.

The cell wall is the end of a chapter and the beginning of a new one. The cell wall is an incipient sense-organ. Evolution constructs it to fit an environment, at first a kind of average fit. For the environment is variable, and in a later evolution the cell gains advantage by mechanisms which react differentially to changes in what comes through the wall. The biochemical mechanisms of this responsiveness are encoded in the genetic record and passed on. One is tempted to use the word "learning" for such adaptations, but the word is not right. The genetically transmitted information, by which a species is able to take account of its environment, is not an achievement of that species; rather, the species is an achievement of the information. The learning is not in the life of the individual but in the transition to a new

species. The individual, like the soul in Plato's account of it, may *know* but it does not *learn*. If the species learns, it only does so by becoming a new species.

By such selectivity cells become responsive to one of the crucial variables of the environment, the existence of other cells. Whether as symbiotes, predators, or prey they are coupled more and more strongly to each other in an ever-changing ecology. Organisms appear, and within them specialized cells and tissues. Whether in the protozoa, the most complex forms still classified as cells, or in multicellular organisms, something appears which may be called learning. In the more complex forms the nervous system appears, and with it reinforcement and inhibition. It should not be supposed, however, that this is the only mechanism of its kind. Even at the purely chemical level we find mechanisms which store acquired information, notably in the antibodies, which acquire resistance to invading pathogens by adaptation on the spot.

To recur to the Neumann machine for analogy, let us suppose that it was not only self-reproducing but had to function in a complex and variable environment. The equipment with which to face this environment could be incorporated in it. But only at the cost of a longer tape, and at some point the tape could no longer be extended. At this point a new possibility would appear, however. Instead of encoding on the original tape all of the detail of response to environmental contingencies, we could encode instead the construction of a new component with a new tape of its own, a *learning* machine, and make provision, perhaps, for a sheltered infancy. The point of the innovation is that the code-description of a machine which learns, which acquires information from and about the environment, can be small compared to what the machine learns. Subtleties of behavior can be learned, can be recorded, which exceed the capacity of the original tape; and they can be learned within the life-span of the original machine rather than at the slow pace of natural selection.

When such a step occurred in the evolution of animal species, an essential limitation upon all previous evolution was removed: the self-reproducing molecule was no longer burdened with the organism's entire stock of vital information. Such a step is of

importance comparable with the beginning of life itself, and deserves to be called a second main stage of evolution. It has little or no significance in the plant world but, tied to the sensory-motor equipment of multicellular animals, it became the dominant theme of evolution thereafter.

The simplest learning mechanisms are of an obvious kind and are quite mechanical in their operation. In the conditioned reflex and in the switching mechanism which is the basis of the large digital computer, the essential thermodynamic condition is again the availability of free energy for the performance of entropy-reducing, order-increasing work. The switching mechanisms transmit flows of energy larger than the incoming signals which direct their behavior. Through reinforcement and inhibition, relatively simple stimuli come to release complex responses adapted to the character and behavior of the environment. The patterning of such responses represents, vis-a-vis the environment, a lowered entropy of arrangement.

Such a description of learning, of human learning or even most animal learning, may be absurdly reductionistic. But whatever else may be involved in such learning, its outcome is one of which this simple, reductionistic account will hold.

In spite of its limited, mechanistic character, in spite of the images of relays and vacuum tubes which the comparison evokes, there are features of relatively simple systems of this kind which ought not to be ignored. Being causally "open" systems, whose future functioning is contingent upon intervening signals received from the environment, such machines are unpredictable in their behavior except as we manage to anticipate what their "experience" will be. After it has been functioning, learning, for a time, the inner form of such a system is unknown to us; information has been written on the *tabula rasa* of its recording tape. It is more than the mechanism that was assembled. A part of the order is the order that was designed into it; but a part is not the order of the drafting table, but the order of a universe, to which the machine responds and from which it gathers information. In this respect, one might suggest, the machine already has that aspect of *soul* which appears in Aristotle's system of ideas. To speak of life, especially of human life, in a machine language is

commonly thought to deny to it the aspect of soul. It is more cogent, I would suggest, to impute this very aspect to the machine that learns. In some ways, indeed, we are rather close to Aristotle or at least we parallel him at a distance. The genetically informed organism has a "vegetative" soul; the mechanisms we are now speaking of, informed by learning, correspond to the Aristotelian soul that is "sensory" and "locomotive."

I have emphasized the separation, in the self-reproducing machine that also learns, between genetic information and information learned. In self-reproduction the tape that guides the process is copied; but the tape which records the biography of the individual machine is not. A new machine must first face the world in innocence, guided only by inherited reflexes. What is learned is lost and must be learned again in each generation. There results a steady state, an average level of sophistication. As in my hypothetical machine, so with the animal species. Sophistication is almost zero for the paramecium, low for the ant and the bee, higher but still bounded for doves and lions. Life in the first stage can transmit structure and variation of structure, but it cannot learn; life in the second stage can learn, but it cannot transmit what is learned.

It was remarked by Weismann, possibly first by Goethe, that death is a biological invention associated with sexual reproduction. Death provides damage insurance for the precious genetic record of multicellular life, while rendering it more adaptive than the immortal cell. Death genetically is the servant of life. Only at the second stage of evolution does death become poignant. The accidental death of a cell loses nothing to the world; but the passing of any learned organism is, in principle, a loss of something unique.

The capacity to learn is an externalization of function, the recreation outside the cell nucleus of a new way of acquiring and storing vital information. The nucleus has its limitations, of information capacity and rate of evolution. The capacity to learn has its limitations too, of which the dominant one is death. The stage is set, at last, for a further externalizing of function, not only extra-nuclear but even extra-organic. This stage, the stage of culture, is dominated by *Homo sapiens* and his late ancestors.

In this stage learned information is incorporated into the environment, and from that environment recovered and extended. If a sheltered environment merely protects the young animal in his first learning, this is not yet culture. If he learns in an environment altered by parental and social influence, learning shades over into education, and this is culture. Culture is information, transmitted extra-organically through material artifacts and social influence. The bees can build a hive. To the extent that this ability is genetically transmitted, it is not culture. To the extent that it is learned in the context of a pre-existing hive, then some part of the vital information of bees has been transmitted without benefit of DNA, and this is culture. It is the evolution of these capacities which removes the main limitation of the second stage. Cultures may die, as cells may; but death is not built into them, as it is into multicellular animals. And through cultures learning becomes cumulative, evolutionary.

Various animal societies may be characterized by the level of culture which they achieve, defined by the ratio of culturally to genetically transmitted information. Bee culture at a low level, beaver culture at a higher, chimpanzee culture at a still higher level, reach a stage beyond which they do not go. Culture enhances the individual capacity to learn, but only to a degree. The parasitic culture of dogs may reach a higher level than in its wild state, absorbing information from the host-culture of man. But once reached, the equilibrium level of animal culture can change only at the slow pace of biological evolution.

In our own ancestry, nevertheless, this upper bound ceased to be effective. From some point on, the level of culture could rise at a rate determined by its own dynamism. The third great stage of evolution is marked, within a single genus, by the appearance of a new *mode* of evolution, non-biological and more rapid by orders of magnitude than the biological mode.

What are the distinctive characteristics of man which, considered biologically, remove the limitations upon cultural evolution? We all know the listing: upright posture; coordination of hand and eye; the voice-ear coordination; increased forebrain capacity; changes of the sex impulsion. There are many others more minor. Some of these changes seem obvious necessary conditions. That

they are sufficient is too strong a claim. Perhaps it is possible, however, to describe the change in some simple and meaningful way, even though we cannot define all the crucial conditions. The other animals learn, but man also transmits what has been learned; he teaches. The other animals modify their environment by living in it, but man also remakes his environment. The other animals copy the order of the world within themselves. They live, as the old phrase says, in accordance with nature. But the individual man has greater freedom from the immediate dictates of perception and desire. He likewise copies the order of the world, but he is productive, "poetic"; he makes artifacts, tools to make artifacts, and tools to make tools. Man likewise makes myths. And in all of these activities he is transferring order to a social and material environment. The storage of vital information is no longer solely in the cell-nucleus, or the brain, but in the environment. A new externalization of function has occurred, and in the measure of it nature lives in accordance with man. In the measure of this externalization, also, man learns that which he has himself produced. A knowledge has become possible that is self-knowledge, a soul "is mirrored there where it may see itself."

The distinctive characteristics of man as a biological organism are connected, it would seem, with the aptitude for culture. This aptitude has three phases, interconnected. The first is the aptitude to be taught, to be acculturated, to be brought up. The second is to appropriate, to use, to modify and even reject that which has been learned from the culture. The third is to produce and to teach, to give back what has been consumed, with those additions and alterations which are the mark of individuality. Someone has paraphrased the Freudian stages of development by three verbs: to get, to keep, and to give. The chief biological novelties in man, those listed and others almost certainly, are the instruments of this reproductive cycle.

The self-reproducing molecule, the brain, and finally the tool and the book—these mark the major transitions of evolution. Each is a way of accumulating that kind of thermodynamic order which has come to be called, by a curious return to the archaic original meaning, *informatio* or information. Evolution has been the elaboration of three variations on a theme. The story of

evolution is a history of nature, under the aegis of the second law of thermodynamics, in a sector of the universe low in temperature but rife with free energy. From one example, at least, we know something of what happens under these conditions over times comparable with the age of our sun.

SONG

By Joanna Stevenson Sampson

What did the children sing
beneath the sun as it
reeled round its tipsy noons?

Pied Pipers are there many that beckon,
lacking, of course, the magic pipe and
the moral hidden within the tale,
yet the song goes out on the huge
haze of afternoon only to stumble
at evening over the thresholds of
dismay and broken gods.

And can I say to the children at noon,
"what do you want so vastly that
the cool spring mornings stretch out
into thin, white roads of longing?"
Dare I question the children at midday
when the echo of their song, returning
at evening, carries the sound
of my own voice?

American panels

ERNEST KROLL

DIGEST

So that he who reads may run
And, running, be informed,
Here's a little food for thought
Already warmed.

MOVIES

Nothing will do but Moby Dick
Must spout in a visible sky,
Hauled out of the ocean of infinite mind
And penned in the sea of the eye.

SUPERHIGHWAY

The purpose, speed; to travel slow,
Illegal; the landscape, to forget;
Just go from where you have to go
To where you have to get.

COUNTRY CLUB

Threatened by no black, no yellow
Peril, the elite unbend intact;
Life upon the links is mellow,
Ringed by its own Exclusion Act.

SUBDIVISION

Driving the thrust before it, arrives
The bulldozer, leveling lots.
Like war in the woods, the shots
Of the carpenters, hammering for their lives.

INDIAN SUMMER

Masonry, those wigwams;
Smoke, not from the Sioux,
Spires from the tribal hams
In backyard barbecues.

SUNDAY

A carwash is the act of faith
Rendered unto the metal host;
Exhaust, about the ride, a wraith,
Hovers like the Holy Ghost.

CONSERVATION

To stop the sneeze,
They fell a wood
And pulp the trees—
And start a flood.

TIME CAPSULE

So that whoever from our wreckage
Draws the buried capsule up
May grasp the truth, set in the package
An aspirin and a paper cup.

And fishers of night catch morning

WILLIAM C. SAYRES

He was surprised. She hadn't, of course, understood about the fishing, but she'd been interested. He hadn't expected a small hasher in a big apron to be interested. With twenty-cent hamburgers you usually got a twenty-cent interest. But in forty minutes they'd exchanged obits (it might just *be* my obit, he thought, if I don't find a way soon), the easy items, not the important ones, but the interest was important. She was twenty-five, new at the Redlip All-Niter, named Rose cut from Rosalie, convinced she wasn't as pretty as she was, and interested. He was thirty-one, an irregular consumer of Redlip hamburgers, named Joe trimmed from Josephus, vaguely certain he'd been presentable before he'd become so thin, and not really interested in much of anything lately, not even Redlip hamburgers.

Because she had the interest, she'd learned more than he. She'd learned that he'd been in the army until last spring. She'd learned that his back had become somewhat disorganized in Korea (so many eyes glazed so quickly, he thought, when you mentioned Korea, as if it were mostly just an unpleasant geographical cliche), and that the horizontal era of convalescence had reluctantly given way to the vertical era of the pension. She'd learned, finally, that his resemblance to a candidate for Goodwill Industries (not as one of the disabled workers, but as one of the things the disabled workers worked on) had something to do with fishing.

"So how come?" she asked, refilling his coffee cup. "How come this business about fishing?"

He took out a package of cigarettes, lit one, and inhaled. "So I'll tell you how come," he said. "Even without dramatic overtones, if I can manage it. First I was in a lot of mud in Italy. Then I got into a lot more mud in Korea. After that I was in a hospital till my back got fixed, or mostly fixed. I never seemed to do much real fighting, but I sat in the mud a lot, till something hit too close. You know what I used to do, though, while I was

sitting in that mud?"

"Pretend you were some other place?"

"Sure. I tried one place after another, trying to get away from that mud. You know, a Waldorf suite with a sexy movie queen crowding me on the sofa, or maybe a booth at a fancy restaurant with the table loaded with steaks and good beer. But the flashy sort of thing didn't work for me, the mud was right there all the time."

"So?"

"So finally I hit on fishing. I dreamed up this beautiful lake, with nice clean water and the sun warming just the top of it, and I'd be in a boat in the middle of that lake, away from everything on shore, and all I had to do was sit there and fish. I still don't know why it worked so well, but I figured out some of it. The way it all was, I was sitting there anyway, in that mud, so it wasn't too hard to pretend I was doing something else that was mostly sitting and waiting. And there was plenty of water around, in the mudholes, so the water part of it wasn't too tough. And even though you had all these guys around, you mostly felt alone, and I mean alone. So that part about being all by yourself was sort of easy."

"I feel that way myself a lot."

"Well anyhow, after I worked on it awhile, I got so things were twisted around just right. I was waiting outside the mud, not in it, and the water was clean, and I was by myself because I wanted to be."

"Sounds okay."

"Sure. Even in the hospital it worked. There was all that waiting, and being by myself, and the bed made a good boat. The water was harder to figure, but it was easier to imagine it was clean. It sounds crazy, I guess, and maybe *I* was a little crazy then. Maybe I had to be to get through it. Anyhow, you can probably guess what I wanted to do first thing, when they let me out."

"Probably follow through on your dream."

"Sure. When I got back, all I wanted to do right away was get in a boat and find a lake somewhere. Because it pulled me through, kind of. So I got my boat, got my lake, and what happened?"

"What?"

"Only one little thing happened, that's what happened. One little thing. It brought back all that mud."

She started to say something, stopped, traced with a short fingernail a crease on her apron.

"All that mud. When I was really in it, the boat took me away. When I one hundred percent really got in the boat, the mud came back. One thing all twisted up with the other, you know. You get one, you get the other. Goes in either direction."

"So don't fish."

"It won't stop with that. Before I came back, it got so fishing meant, well, good things, everything I didn't have then. So now whenever I try to look for good things, the mud comes along. Maybe I sound like a psycho, but I'm not. I keep thinking I can work it out. But I'm not ready yet, not enough, and in the meantime I got to be careful. I get a lot of hope, and the mud buries it. So I better not get a lot of hope." He reached for his wallet. "How much?"

"Eighty."

He handed her a half-dollar, quarter, and nickel. He thought: she didn't have to touch my hand like that, she could have had me put the money on the counter.

"Look," she said. "Talk about it some more when you come back."

"Sure." Did I say I was coming back? he wondered. Careful now, she's just a hasher; still, she's interested, and I liked the way her hand felt then.

"I work weekdays," she said. "Or weeknights, however you want to look at it. Six to three."

He wanted to say something casual, something about the weather maybe. Why can't I? he wondered: she's just a hasher, a six to three hasher. He moved toward the door. She's stronger than I am, he thought, and I don't know if I like that.

He came back once the following week, twice the second week, and four times the third. It was late November then, and on Friday of the third week she asked to mend his overcoat.

"No snow yet," he said. "I don't care if it doesn't button up

just right. You got plenty to do without worrying about my coat."

"I wouldn't mind," she said.

"Mind your own business, that's what you can mind. Another thing, you've been loading my hamburgers. I get twice as much meat as anybody else." Why do I chew her out? he thought. When she said she wouldn't mind, did she mean mending or worrying? Anyway, there's no call to go chewing her out. "Coffee's good tonight," he said.

"I always was good at making coffee." She filled his cup again.

One night in early December he finished his second piece of pie, and took out a cigar. "You mind?"

"No. I had a favorite uncle who liked cigars, and they always smelled okay to me. Except in closed cars."

He lit the cigar, puffed at it slowly. "You did a swell job on the coat," he said. "But the old buttons were strong enough."

"It's the thread that has to be strong. And the buttons were flaking off. I don't know what they were made of, but they were flaking off."

"So what are *you* made of?" he asked. He took a long puff. I'm afraid to hear, he thought. Not because of what it will be, but just because then I'll know more about her. Why do I come back here?

"Nothing much," she said. "I grew up in Peoria. Father worked in a hat store. I helped out after school, sorting and checking. Finished high school. Even went to night school for awhile at some place that called itself a college. But I gave that up early. We never had any money to speak of, lived in a four-room flat near downtown. But my dad was glad I finished high school. He never got that far, my mother neither. When she died, I came here. We heard there was plenty of work, with that housing development going up. That was three years ago." She paused. "Ordinary?"

"Ordinary enough. Safe." Don't ask her anything else, he told himself. And suddenly, with real pain, he discovered that he wanted to, had to.

On December fourteenth the wind started early in the morning,

and by ten o'clock was gale force. Leaves long piled were unpiled, and thin trees were snapped. By three o'clock in the afternoon the sky was so dark the street lights were turned on, and several were shattered by bursts of hail that disappeared when the wind warmed about six o'clock. Joe stood near the Redlip All-Niter and looked at one of the shattered lights. There's something happening, he thought, or something waiting to happen. He went inside, ordered coffee from a woman who had the strangest face he had ever seen. Like Elizabeth Taylor's in the final stages of decomposition, beauty clinging to carrion. It's part of what's happening, or going to happen, he thought. Things like that have meaning, or nothing does. "Where's Rose?" he asked.

"Not here yet. First time late this month."

That, too, he thought; that has meaning too. So does the night; it's waiting, maybe for the hail to come back. He gulped down his coffee. "Tell Rose I was here."

"You Joe?"

"That's right. Tell her I was here."

"I'll tell her. That all?"

"That's all." He left a quarter on the counter. When he was at the door she said, "You be back?"

His fingers ached. He found he was gripping the doorknob too tightly. "Yes," he said. The phrases "fingers ached . . . gripping doorknob tightly" bothered him: they were in my throat as soon as my hand hurt, he thought. Stale words, and I was almost saying them to myself, or to that waitress. A night like this, I'd say anything to anybody. Or almost.

He was back at 3:00 A.M. It was oddly warm and windless outside, but he thought the wind would come again any hour now, and the cold with it. He took his usual stool.

"I heard you were here earlier," Rose said. She was stacking glasses. "Was it anything special?"

"Yes."

She took off her apron. "Then why didn't you wait? Or come back sooner?"

"It didn't matter when I told you. We couldn't leave anyway until you got off work." He was sweating, and his head began to hurt.

She came around the counter, sat on the stool next to his. "What do you mean, leave?"

"We can talk about it later—I mean I want you to come with me somewhere. It won't take long, but I don't want to start talking about it now." He wished his head would stop hurting and wondered if he should stand up now, to show her he was decisive. But he wouldn't he knew, because he wasn't. "You have to come with me," he said weakly.

"I have to do no such thing."

"Yes," he said. "Yes, you have to come with me." He wiped some of the sweat from his face with a paper napkin. "Please," he added.

She sat quietly for a minute, two minutes. "All right," she said. "How are we going? Wherever we're going."

"My car. It's outside, a block or two away. I can bring it around." Stupid, he thought, stupid: the car's almost in her lap, so I say I'll bring it around.

"We can walk," she said.

Of course we can, he thought. Of course she'd say that. I wish my head didn't hurt this way. "You have to lock up or anything?"

She motioned toward the kitchen. "Pete takes care of that. I'll get my coat."

Outside they walked quickly down the street toward the car. "It's going to rain," she said. He nodded, realized she wasn't watching him. "Yes," he said, "That's why we have to hurry." He kept brushing her arm with his, wanted to take it, but didn't.

He headed the car west out of the city. The wind was stirring now, and a few drops of rain hit the windshield. Not enough to turn on the wipers, he thought, but we'll have to hurry.

"You already said that," she said.

"Said what?" he asked.

"That we'd have to hurry."

"Oh, I didn't know I said it again, out loud again."

She smoked a cigarette, looking away from him, out the window. After a while she said, "We're going to the lake."

"Yes."

"Why tonight?"

"Last chance before winter, before ice closes it."

"Maybe it's already frozen."

"No. I checked this afternoon. That's when I got the boat ready."

She put out her cigarette. "You think I'll help?"

"I don't know. I can't do it alone. But it's kind of a last chance for me, the last before winter, and it could be the last before all the winters after that. But if you can't help, there's nothing. It might as well be winter; I can't do it by myself." Shut up, he told himself: you're like a baby, the way you run off, spill yourself all over the place.

At the lake he parked the car under some trees near the shore. He opened the trunk, and took out tackle and foul weather gear. "It's going to rain any minute," he said, handing her a slicker and hood.

"You don't need the poles," she said. "You don't really have to put a line in."

"Yes," he said. "There's only this way. And I have to try it the other side of the buoy, in a deep place there, where it didn't work before."

They put the tackle in the rowboat. The stern was already touching the water, and she climbed back to it and sat down. He untied the rope holding the prow to the shorestake he had pounded in that afternoon. He started to coil the rope, then bunched it together and dropped it in the boat. As he pushed off the rain was starting, and the wind growing.

While he rowed he strained to see the buoy, but it was too dark. The clouds were slipping fast over the moon, and what light came through showed only the roughness of the water and the distance of the shore. "Are we close?" she shouted. "I don't know," he shouted back.

Why tonight? he wondered. Is it just that business about the winter closing in? That's part of it, sure, but maybe the feeling I have is more important, the feeling about a day and night like this. The wildness means something; it's one of the times change can take place, maybe that's what it means. If you want to be different, maybe you need a day that's different. And maybe you'd better forget that stuff and keep this boat from swamping. "It's right around here somewhere!" he yelled. "Close enough, any-

way!" He folded the oars back in the boat and dropped the anchor.

The boat pitched and jerked at the anchor. He looked at her, huddled on the stern seat in the slicker and hood. What's she thinking? he wondered. Why did she come? Well, she came, no sense going beyond that. He reached for the tackle, picked up his spinning rod. "Come up here!" he shouted. He moved aside and pointed to the space next to him.

As the boat plunged and bucked she crawled along the bottom to the oar seat. He pulled her into place beside him. He bent close to her ear and lifted her hood flap. "I'll need you here to steady things," he said, "and I can't keep shouting back there to you." She nodded.

He tried to see into the tackle box, and his head began to hurt again. After a while he closed the box. It shouldn't matter, he thought: it shouldn't matter at all, but it does. "What's the trouble?" she said. "I forgot the bait," he said, knowing it sounded foolish, waiting for her to let him know just how foolish she thought it was. "Use a lure!" she said. "Don't carry any," he said, confused that she didn't sound angry. "Try this," she said, pressing something into his hand. It was one of her earrings.

He held the earring to his cheek for a moment, wishing he could let her know what she had done, but he was sure only that it was good, and not at all sure he could say just what it was. He tied the earring on the line next to the hook, added two buckshot sinkers, and made a short cast with the wind. It was hard reeling in, and he wondered why he had bothered with the sinkers. He cast again.

The rain was heavy now, and he could no longer see the shore. As he cast and reeled, the past began to come to him again, and it was as if he were casting for pieces of it and drawing them to him. The wind and the cold black spray and now the slowly rising thunder carried to him the touch and sound of things dead and dying and above all brought to him the sense of waiting forever for what might be nothing. The boat shuddered, and shuddered again, or was it the mudhole shuddering as the shells came over and over and over? And what was the cold he now felt, was it of this day or that? And was all he was able to do before much more

than the striking of water with an earring?

How long he cast and reeled he did not know, did not care, but as the past came and swallowed the boat, there was still the touch of another person, one who had come because he had wanted it and had asked it. There was an arm, an elbow, pressed against his side, and coupled with the smell of wet slicker the fainter, yet stronger, smell of perfume which must have been cheap, but which then had nothing to do with price, and these were things he had not been able to believe in when the mud was real.

And what was coming to be was a fading of death into a single night, a wild night, but this night, one which would very probably pass, one which would pass not so much away as into morning. He breathed deeply of the slicker and the perfume, and bent his body hard against the elbow. He closed his eyes and turned his face into the rain, and for all the stinging knew it as rain, the rain of one night.

And then he heard her scream.

She was pointing to the bottom of the boat. Two crests had broken over the prow, had swirled into the water already there, had started the boat listing and drinking more of the other waves. He reeled in fast and groped in the water under the seat for the bailing cans, then sprawled and splashed from bow to stern until he had found them. He handed one to her, and together they began to bail.

He bailed until his arms and shoulders and back hurt as no part of him had hurt for many months, but he knew and exulted that it was the bailing that was hurting him. His head did not hurt at all: it would hurt later on, maybe many times later on, he supposed, but less than before, and he found he could believe in a day when the hurt would be too slight to matter, or would not come at all. Maybe he was wrong, but at least, he thought, it was something that could be believed. And in these moments, with stomach half-sick and body aching, his head did not hurt. He kept bailing.

The morning came. It was not something he could feel coming, or measure coming; he heard his bailing can drop to the bottom of the boat, realized that he was looking at a tackle box so visible that it must be morning. He lifted his head and looked at her: the

bailing can was still in her hand, and her head was bowed toward it, but she seemed no longer able to decide to drop the can or lift her arm. He tugged at the can until she let go, and now she turned to him.

He watched her face, wondering if she would curse him, or cry. She smiled, took off her hood, and shook her hair in the morning wind. It was a soft wind, with no rain in it, and he was filled with the glory of what she was doing. He fumbled with the tackle, detached her earring, held it out to her.

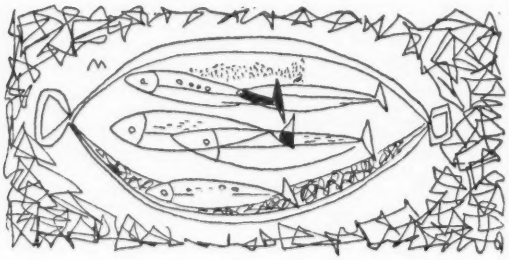
She smiled again, and in a movement so swift he perceived it only when it was done, pulled off the other earring and put it in his hand. It could, he thought, have brought pain to her, the way she had done it. But he did not, he found, wonder about this; he accepted it, and thought that there could, after all, be something good about waiting. He put the earrings in his pocket. "Wet enough?" he asked.

"Almost enough."

"Tired enough?"

"More than enough." She hesitated. "Is it better for you?"

"Yes," he said, "it's better." He put his hands on the oars, his arm across her back. 'You know it's better." He began to row toward the shore.



Man of the hunting age

NORMAN B. TINDALE

During the greater part of the Pleistocene, all men were hunters and food gatherers, and hunting and foraging practices remained well-nigh universal until about ten thousand years ago. Australia is the only large country where Old Stone Age hunting men survived until modern times without being in more than limited competition with people knowing other modes of living. By the study of such men, their behavior, and their activities over a whole continent, we may learn much which will aid us in establishing sound theories about the ways of life practiced by all men, including our own ancestors, during the Ice Ages.

There are several intriguing features of the life of the Australian hunter which are important for our study. In Australia we are faced with the seeming paradox that simple hunting peoples, who possessed material aids no more complex than those of the Upper Old Stone Age, seem to have what are called the world's most complex systems of social organization.

The point of view may be wrong. When looked at from the Australians' own way of living, the complex systems become the patterns woven by a simple adherence, over long periods of time, to sets of obvious rules of conduct; the exceptions are merely the results of the many compromises and adjustments which have been made necessary by human shortcomings. The seemingly-simple stone tools, on the other hand, are discovered often to be highly complex end products of long experience and empirical knowledge. Stone Age man's technical achievements indeed reach a climax in the multi-purpose weapons and the kinds of composite tools used by the aborigines of the Great Western Desert of Australia. Each piece of such material equipment is either a purely temporary tool or implement made, used, and discarded on the spot, or if intended to be kept, is made so that it will serve several different and highly-essential functions. To serve these purposes it has to be as free as possible from the disabilities of

fragility, perishability, and surplus weight, and in the course of its life as a stone implement it may be rechipped to a very different form than when it was new and serve several purposes as well.

We can learn much of importance by observing the Desert peoples' ability to make use of one of the world's very difficult environments. In such a situation there is great premium on the discarding of all surplus personal property, but strong emphasis on zoological and botanical knowledge and on memory of the geographical patterns of one's country. Much skill is devoted to achieving rapidity and ease of travel on foot; this is essential in a country entirely lacking in aids to transport and without either assured stores of food or very obvious sources of water supply. A man must have the ability to match the chances of finding water against the capacity of his family to travel, and since he has no ready means of storing nature's products except by leaving them where they are, he has to gamble that he, his wife, and family can find a day's food on each day of the year.

Deductions from the prehistory of the Australians suggest to us that, at different times during the last phases of the Würm Glacial, at least three successive groups of hunting men moved towards the equator out of southeastern Asia and went beyond it, down through the Indonesian corridor to Australia. These three waves of people became the Barrinean, Murrayian, and Carpentarian hunters of Australia. During the same time interval, other men from almost if not quite the same parts of eastern Asia, moved coastwise and northeastward, following other game and adventure, to become the men of Tule Springs, Sandia, Folsom, and the other early hunting cultures which entered the Americas. They travelled from Asia over the cold and windswept plains, which once lay where now roll the waters of Bering Strait. Details of their probable history are given in a masterly analysis by Wormington.[1] It is the thesis of this paper that, although now far sundered in time and space, the ways of life of the living Australian hunters may parallel those of these Americans and many other extinct hunting peoples. We can receive great help in putting flesh on the bones and handles on the stone relics of the first hunters of America by seeing how these Australian

aborigines lived. Their behavior may help to elucidate the whole pattern of prehistory in the Pleistocene.

Recently, in the *Records of the South Australian Museum,* I published an account of some gains in the field of Australian prehistory.[2] Here I shall link a few of the salient points of that paper with several very new discoveries from various parts of Asia. This summary may serve as a framework on which to set some items of theoretical import.

Excavations by Harrisson in the Great Cave of Niah in Borneo have disclosed relics of people of several culture phases, extending back from the present day for at least thirty-nine thousand years.[3] The time interval is controlled by at least two Carbon 14 samples. In the top layers of the Niah Cave are later relics left by the gatherers of that strange delicacy, the gelatinous bird's nest, made by a species of swiftlet (*Colocalia*), which once, in the days before China became communist, provided soup for the rich man's table. At the bottom of the Niah deposits, nearly forty thousand years earlier in date, are large and simple chopping tools, made from pebbles.

From the descriptions given of these tools and the comparisons that have been made with other pebble tools, we are led to the conclusion that the Niah Cave pebble choppers are very similar to ones present in Australia. The Australian examples are found in situations indicating they were in use before and during the last cold phases of the Würm (Wisconsin) Ice Age. In Australia some kinds of these tools have been dated, on geological evidence, at a time before the Post-Pleistocene eustatic rise of sea level, and their first appearance may have gone back to some eighteen thousand years before the present. This, the earliest of the known Australian archaeological implement series, was some years ago named the Kartan Culture.

Kartan people had as their most common implement a crude chopping tool typically made from smooth, rounded, usually elongated quartzite or other suitable rock pebbles. These implements weighed approximately twenty-two ounces. They were fashioned by breaking off one face from the stone, leaving a sharp cutting edge on the core part of the pebble. This cutting edge could be further improved by stepped rechipping, and if it was

used again and was resharpened several times, its shape became rather characteristic, and the whole implement assumed the form of the one called "sumatra," or "sumatralith," by archaeologists. Many of these pebbles, being general purpose tools, might bear bruise marks of casual use as hammers; in addition many hammerstones of more orthodox forms have been found associated with them.

Kartan people used several other crude forms of stone chopping tools. One implement is named the "horsehoof" because of its fancied general shape. This may have functioned as an adze. It seems evident that Kartan implements in general did not have any form of handle as attachment, but were held directly in the hand.

The dominant forms, "sumatra," "horsehoof," and another discoidal one known as a "karta," have been found in many places in Australia and Tasmania. On Kangaroo Island, off the south coast of Australia, for example, there are over two hundred known sites. Similar styles of implements have turned up in Indonesia at Atjeh (Northern Sumatra), and on Luzon, as well as in Borneo. They occur on the southeast Asian mainland at various places extending north from the Malay Peninsula to Tonkin and Hoabinh, on the borders of South China. Just before the Niah Cave finds were reported, Maringer described very similar implements from Japan, which he likened to ones found at Pajitan in Java.[4] The Japanese examples were discovered by Mr. I. Aizawa at Gongenyama, near Isezaki in Gunma-ken. They were considered by Maringer to be late Pleistocene in age, with a later horizon, Gongenyama III, dated very tentatively at the Pleistocene-Recent boundary.

Some writers have used the name "Early Hoabinhian" to embrace the principal finds of this kind in eastern Asia. The term "Hoabinhian" originally was applied to pebble chopper implement horizons containing also some edge-ground stone tools; the addition of the prefix "Early" seems to register the absence of such edge-ground tools. In my opinion the term "Hoabinhian" should be restricted to the edge-ground tool horizons and the culture term "Kartan" as named in Australia should be recognized as including the eastern Asian finds of exclusively Palaeolithic implements of the pebble-chopper series. It seems probable that

implements of Kartan types will be found to occur throughout southeastern Asia.

Assuming the existence of a real relationship between the Kartan cultures of Asia and Australia, we should become interested in establishing what we can about the people who might have been makers of such types of implements. Was there a particular type of human being who used these implements, or had they been in use so long as to be shared by more than one ethnic type of early modern man?

There have been many movements of people out of continental Asia. As already mentioned, at least three early ones are known to have come down through Indonesia and into Australia and three or more are postulated as having entered America across Bering Strait. We may in fancy liken them to laboratory samples, drawn at long intervals of time during the late Pleistocene, from the great experiment of the making of modern man in Asia.

Let us look at those who went south. In the presumed order of their withdrawal from Asia we may list them, according to Birdsell, as follows: (a) the Negritic dark-skinned, crisp-curly-haired Barrineans; (b) the stout, light-brown-skinned Murrayians, with low-waved hair; (c) the dark, spindle-shanked Carpentarians, also with low-waved hair.[5]

They were not the only ones. If we look again at the chain of islands connecting Australia with the Asiatic mainland we can see preserved on the various islands of Indonesia examples of still later waves of peoples who made their way out of Asia in protohistoric and historic times. I need only remind you of the golden-brown-skinned people of Bali and their still-treasured Indian culture of two thousand years ago.

What do we know about the Negritic type of men? They were the first people sufficiently adventurous or skilled in handling rudimentary watercraft to shift away from the continent of Asia, cross the narrow water barriers of Indonesia, and enter the Australian world. They may have been one of the earliest types of modern men in southeast Asia.

As we know him today, the Negrito is under five feet in height, dark-skinned, with crisp, curly hair, a body with a small, light-bony framework and a rather juvenile appearance, even in old age. He

lives in small, widely-scattered hordes or enlarged family communities in places which are uniformly climatically uncomfortable to live in. His are the only kind of people on the Andamans, those isolated islands in the Bay of Bengal. Like the Semang, the Negrito lives in the uninvitingly-hot and wet mountain rain forests of the Malay Peninsula; others camp on the most inaccessible mountain tops of Palawan in the Philippines. Negritos hunt and forage in the rain forests along the almost vertical slopes of the mountains of New Guinea. Others live in the mountain areas of New Britain, in upland Timor, in the rain forests of the Atherton Tableland of Queensland, and until last century they were the only inhabitants of the cold, wet, and dismal forests of the lonely island of Tasmania, at the very periphery of the inhabited world.

Wherever we find the Negrito he is a hunter. Except where he has picked up better equipment, such as bow and arrows or blow guns, from contact with more advanced peoples, his technological equipment has been of the simplest—spears, clubs, pieces of shell as knives, and stone tools made from large pieces of stone. These seldom show much improvement over those which his ancestors used in the Ice Age when perhaps he was the aboriginal man of southeastern Asia.

The first invasion of Australia had to be delayed until the invention of some form of watercraft, such as a raft or canoe. This was the minimal equipment necessary to enable man to cross the several island-to-island water gaps, each up to twenty miles in width, which separated Asia from Australia. These gaps must have continued to exist even during the periods of greatest cold in the Ice Age, at which times so much water was removed from the sea and stacked on the land as ice, that sea level on stable foreshores in tropical areas was lowered by an estimated 250 feet or more and many places which are now islands became connected to the mainlands they adjoin.

In Australia we find relics of other stone tools, of times later than the Kartan, which have been given the name of the Tartangan Culture. They also are believed to have been associated with Negritos. The Tartangan Culture phase disappeared on the Australian mainland at least five thousand years ago (according to the evidence of Carbon 14 dates), but modified forms of the

Tartangan tools remained in use in Tasmania until modern times. It would seem that the Negrito, child of the Eastern Tropics, and once a dominant there, lived through changes in culture style and managed to survive until today, but only where he was able to find an area of refuge such as an island or an inhospitable mountain rain forest in which to hide away from culturally more advanced types of peoples who often were taller and more powerfully armed, or from technologically better equipped people who pressed into his domain. When we look from Australia, at southeastern Asian prehistory, we seem to see that the Negritos, with their suites of simple stone tools, were only the earliest of several different peoples who moved in there during the Ice Age and, by wandering out into Indonesia, came to be preserved in the Australian area.

The Murrayian aborigines of Australia seem to have come out of Asia after the Negritos. Their cultural equipment of projectile points, discoidal adzes (probably including ones with lashed-on and with resin-fixed wooden handles), can be presumed to reflect the general level of culture attained by people in southeastern Asia when they left there.

The last invading group, the Carpentarians, who were the third to enter Australia, appear to have been sufficiently long delayed in their departure that they were able to acquire some of the cultural novelties which marked the level of culture at the transition from the Palaeolithic to the Mesolithic period. This was the time when the edge-grinding of axes already foreshadowed the coming of Neolithic folk interested in felling forest trees, and the slash-burn agriculturalists, whose garden-growing techniques were beginning to be evolved in tropical Asia. Neolithic gardeners entered Indonesia at a still later time but failed entirely to establish themselves any nearer Australia than on the islands near Torres Strait.

Birdsell has pointed out physical resemblances between the Murrayian aborigines of Australia and the Ainu aborigines of Japan, and much has been made by anthropologists of the physical resemblances of the Carpentarians and some of the peoples of India.[3] There is rich material for study here, but it is to the stone implement cultures of the living Australian peoples that I shall now draw your attention.

Much can be learned from the living people which will be of vital importance in the over-all study of prehistory. We can see that, although we have no direct evidence as to the type of man associated with Kartan culture relics, indirect inferences have led us to the conclusion that in southeastern Asia the Negritos may have possessed this type of culture when they began to move out into Indonesia. This does not tell us whether they were the only ones to possess these implements. It is indeed quite likely that such implements had been in currency so long that their use already had spread far and wide through many parts of Asia and were shared by peoples of more than one ethnic type. We are likely therefore to be able, by study of the succession of cultures, to learn much about what was taking place in southeastern Asia during the Late Pleistocene, for it was from there that all these people came, even though we may not always know which physical type possessed the implements we find.

Areas of study on which the Australian living cultures throw strong light are these: (a) the modes of primary and secondary knapping of stone implements; (b) the development of the final forms of implements by continuous processes of sharpening and rechipping, processes not clearly comprehended by some American and European students; (c) the use of sinews, rawhide, gums, and mastics in hafting—by their presence during the active life of the implement each tends to leave traces of a distinctive character on the parts they helped to protect either from resharpening or from casual injury; (d) the use of smooth stone pressers in making fine tertiary flaked edges, as seen for example, on blades of *jimari* type, such as described by Tindale;[2] (e) the influence of bone and wooden pressers on the form of pressure-flaking developed on blades and projectile points; (f) the effects produced by wooden mallets and hardwood tappers, including boomerangs, as used in the retrimming of blunted stone adzes and chisels.

Use of these techniques, and modes of hafting, tend to be registered on the tools themselves: a sharp edge where the resin haft has protected it from abrasion or injury during use, a deliberately blunted edge where sinews or thongs have been wrapped over it, a style of fine chipping only achieved by special methods. All of

these may serve as aids in the identification of the ways in which the tools have been used.

Without going into all details of these techniques, I assert that many types of Asiatic and American tools—the adze, chipped-edge axe, and projectile point varieties—show traces in their mode of working, which can be interpreted as being due to the use of resins, gums, or mastics in the hafts. It is not altogether surprising then to find that although they are not well known, several examples of gum (presumably piñon resin) hafting have been discovered in the western United States. It seems clear also that the mineral pitch hafting of knives, etc., in California is not a special local development, but merely one type of plastic haft. Resin, gum, or mastic hafting may indeed have been an almost universal mode of mounting in Upper Palaeolithic implements.

Many techniques of stone implement making are represented in Australia, but probably not all. The most advanced forms of flint working practiced by Australians are probably those using pressure. Here various effects are obtained by using wood and bone compressers in removing flakes. It is not generally known that one of the steps necessary in making a pressure-flaked blade is that the hammer-flaked edge should be dulled by rubbing it against a stone so as to blunt the edges. Only then can the bone or wooden presser be used to take off the rippled surface flakes which make pressure-flaked implements such beautiful examples of the stone worker's art.

The application of our knowledge of Australian methods of stone working to the interpretation of the work of other peoples may yield results of much interest. Thus the examination of points of Yuma and Folsom types from America show that the edges were abraded before pressure flaking was applied. This fact had not been noticed or understood before the Australian evidence was available.

The method of flaking the butt of the Folsom point is one which cannot be explained by studying the Australian techniques. However, there are some mistaken ideas about this implement which should be discussed here. The assertion has been made recently by several authors that the fluted base of the Folsom projectile point is one known only from North America, and the presumption is

made therefore that it was entirely local in origin. Mewhinney and Chard can be cited as giving recent opinions.[6] This could be so, but we have to look westward from America to the Asian homeland for the first record of this style of projectile. Lawrence described and figured an example of a Folsom-like projectile point, with well-fluted butt, from Japan.[7] It was one of the types represented in a collection of 125 stone implements obtained by his son at an exhibition in Kiolo (presumably a typographical error for Kioto). The point with fluted butt which he figured was of gray hornstone, and is shown as 3.5 cm. in length in the natural-sized illustration he gave of the specimen.

Projectile points reminiscent of early North American types are reported from Patagonia by Ibarra.[8] They suggest the wide range over which the idea of pressure-flaking moved once it was known. From Australia to Japan, Japan to Colorado, Colorado to Patagonia—these are great distances for an idea to travel. Can we draw a general conclusion that man made very wide and rapid movements as a hunter? Is it too early to make positive dicta about local invention as against culture transmissions? Those who are wedded to the idea of independent inventions so often find that new discoveries at intermediate points tend to vitiate their conclusions.

C. S. Chard made an analysis of the growing literature on archaeological research in Siberia and has found that the heartland of Siberia played little or no part in the early development of modern man. He says the indications are that the area was uninhabited prior to about twelve thousand years ago. If this is the case we must look elsewhere for the main areas of development of modern man. Does the data not point towards the coastal lands of southeastern Asia?[9]

Relics found along the Pacific coast of Asia and in areas extending down into Indonesia and up into the Amurland basin, as reported by Maringer, have been suggested as being the earliest and the only ones which might have been ancestral to the American cultures. What Chard has not noticed is that the same cultural sequence which appears in the Americas seems to have radiated southeastward out of Asia towards Australia. The activities they represent were already going on at the front entrance of

Australia and on the Pacific margin on the Asiatic continent, at times long anterior to the times of the suggested northward spread towards Amurland, Japan, and the Americas. When the significance of these facts is better appreciated, much reorientation in thinking will take place.

Omission of study of the Australian evidence has warped the thinking of some other recent workers. Loewenstein, for example, discusses the indications furnished by the presence in the Malayan Neolithic of a type of knife called *ulu* among the Eskimo.[10] In its most primitive form, as found in Alaska, he suggests that the *ulu* is a uniface semi-discoidal flake about 10 cm. in greatest diameter, with a handle or haft made from a piece of wood or fashioned from lashings of osier. In an example from Hotham Inlet, Alaska, described by Loewenstein, there were fish scales wedged in the handle, indicating one of its uses as a fish cleaner. The example he used in illustration was described as a "leaf-shaped blade of hornstone with primitive handle made of osier, wrapped backward and forward longitudinally and held firmly in place by cross twinings and weaving of the same material." His figure shows that the particular "leaf shape" he refers to is a discoidal rather than a pointed one. A second example from the same place is described as a "primitive blade of chert or flint, inserted in a handle of wood." The length is not given but the scale of his accompanying drawing implies that the diameter is 10 cm.

Having studied the distribution of many examples, Loewenstein makes the suggestion that the direction of movement of the idea of making these implements was from a center in the Lake Baikal region. He visualizes them as moving outward both towards Malaya and in the direction of North America. He dates the whole sequence of events impossibly late, as being linked with Mongoloid movements of shortly before 500 B.C.

What does the Australian evidence say? It is evident that the presence in Australia of the *jimari,* essentially the same implement, which occurs first in the Tartangan of 8600 B.P. and survives locally in the living culture of a part of northwestern Australia, makes necessary a revolution in thinking. This basic form of discoidal knife, whether it be termed *jimari* or *ulu,* was already well established in the equipment of men long prior to the time

he cites, and if anything can be deduced from its distribution, the direction of movement of the idea of making them might have been northward out of southeastern Asia rather than southward into the area. Obviously this invention long antedated the end of Pleistocene time and was not one made in the Arctic North.

Let us look again at the ideas recently expressed in Chard's paper. He makes a provocative suggestion that the New World cultures, other than those represented by the earliest chopping tool tradition, may all have been evolved independently in the Americas. In fact he seems to be returning to an old "isolationist" view, once favored when there was little knowledge of cultures in the Alaskan area and in eastern Asia, and he goes so far in the opposite direction as to suggest that, after being independently evolved in the Americas, there may have been some late reversed cultural transmission of ideas and implements from America back towards Asia.

Taking the Australian and Indonesian data into consideration, how can he account for a repetition of the late Palaeolithic and Mesolithic sequence found in America, right up to a pre-pottery microlithic industry phase, in the Indonesian corridor, and in areas leading down to Australia? Could this have been a second area of development independently following substantially the same sequence of evolution? If so, why should the traces of such an evolution survive in a neatly-descending series as one moves out from southeast Asia towards Australia? Perhaps the coincidences will be found to be too great for Chard's new ideas of independent evolution to survive. Surely we must look for a generalized homeland of the cultures of *Homo sapiens* in southeastern Asia. Not only did island stepping stones lead men southeastward into the Pacific but the coastal margins of Eastern Asia led other men carrying the same or similar ideas along another corridor towards Alaska and the Americas.

There is increasing evidence that modern man, as represented by the men of Cro-Magnon and other types, was a relatively late comer in western Europe. Perhaps then southeastern Asia, with its varied climates and changing shorelines, was a kind of "Garden of Eden" where the first *Homo sapiens* forms may have become differentiated from earlier *pre-sapiens* men.

Here then is a quarter of the globe in which research must be focused during the next decade. Some living representatives of early forms of *Homo sapiens* are still seen to be surviving in Asiatic jungles as well as in Australian deserts. We can still appreciate their physical makeup, and in the Australian area a few people still make and employ the Old Stone Age tools once used by many men. These hunters can still demonstrate how they, and their fathers before them, practiced arts and crafts which we have forgotten.

There are many other directions in which the study of the Australian aboriginal can yield important data for the understanding of early man in other parts of the world: in social organization, in techniques of living, and in the manner in which ideas spread from tribe to tribe. Let us take, for example, some ideas centering on sizes of tribal territory and population. One of my most eagerly-pursued long-term projects has been the plotting of the distribution of the nearly seven hundred tribal units of Australian hunting men and the determination of the internal structure of the tribes, the hordes, and family units, of which each tribal entity is composed.

It may be reiterated that Australia has a large area of territory occupied by hunting peoples in an approximately uniform state of culture. With relatively few exceptions, the coherence of the tribal units is based on relatively simple laws which can be demonstrated as likely to be true because of the large number of examples which can be tested. Other things being equal, it seems that tribal coherence is based on ability to communicate through possession of a commonly understood form of speech and through opportunity to meet as members of a common community, at least for periodic exchange of ideas and mutual sharing in rites, ceremonies, and marriage arrangements. These linking factors are ones strongly affected by man's capacity to travel. Therefore, except where special conditions exist, strongly linear tribal territories are rarely present, and compact subrectangular or even subcircular territories are more common.

Let us consider the shapes of the many tribal areas on the map of Australia I published.[11] The principal boundaries have now been confirmed by much additional field data being gathered for

a second edition, which is in preparation. An ideal tribal area, for a centrally-located tribe, approximates a five- or six-sided figure (with a mean of 5.5 contacts with neighboring tribes), thus approaching the ideal hexagonal shape of the cell of a honey bee. This form indicates the powerful influence that distance has on relations between tribes and the reality of the principle of isolation in bringing about tribal differentiation. A hunting tribe at its greatest extent seems to be able to range over an area of no greater diameter than 200-250 miles, and tribal areas of these great dimensions are only attained when the area is so arid that fifty square miles or more of territory is necessary for the year-long support of each person. At such a low density of population, isolation and the difficulties of travelling to meet together tend to prevent the coherence of more than from 250-750 persons. A mean figure of 500 has been assumed as likely for the population of an ideal Australian tribe, although Birdsell thinks on very valid grounds that this figure may be a little too high.[12]

It is of considerable interest to note as we go to areas which are more fertile, it is not that tribal numbers increase but that the area used by the tribe generally becomes smaller. In areas which are so "rich" in terms of occupancy by hunters, a density of one person to three to five square miles of territory is possible, the tribal unit of population rarely exceeding the above-stated mean. Even from the brief outline given, it is evident that principles governing size of tribal area and general shape and density of occupancy noticed among Australians may help us to appreciate the *milieu* in which the several developing forms of *Homo sapiens* lived in Asia during the late Pleistocene and help us to understand something about the hordes of hunters who invaded the Americas.

Many other aspects of tribal contact and isolation can be better understood when we look at Australian data. For example, the gathering of data on inter-tribal marriages in Australia has shown that a mean of 86 per cent of marriages are within the tribe and therefore 14 per cent tend to be intertribal.[13] Using this and other data the likely rate of gene exchange has been determined, and models constructed by Birdsell have led to a considerable advance in our understanding of the way in which Pleistocene population of hunting man may have been modified and influenced.

Without laboring these points, it may be said that we have powerful and as yet insufficiently-exploited sources for the determination of the mode and tempo of growth, not only of early populations of modern man but also of the factors which governed physical and cultural contacts between types of men. Australia is a living laboratory which must be staffed as quickly as possible by the best of research teams so that the unique situation in which Old Stone Age man has survived until modern times may be well studied before the inexorable advance of modern civilization destroys it.

Addendum

The substance of this paper was read in the Summer Lecture Series at the University of Colorado, Boulder, on July 8, 1959. When the paper was in the final stages of typing, a paper by Bushnell and McBurney became available.[14] It was found to cover some of the same ground this author had traversed in criticizing the conclusions of Chard, but it differed in a suggested alternative solution. Whereas Bushnell and McBurney, without the aid of the Australian evidence, had concluded that the early home of modern man might have to be sought in the Middle East, I had suggested the center of distribution would be found still further east, perhaps centering in southeast Asia, in areas beyond the eastern extensions of the main influence of the Lower Palaeolithic hand-axe complex.

Every implement type in Australia, perhaps other than the late influxes of edge-ground axes, is in the true Palaeolithic tradition. Types found include Kimberleyan biface projectile points which are so closely a parallel to those of the Palaeo-Indian cultures of the Americas that they must be assumed to have had common ancestors in southeastern Asia in the Upper Palaeolithic. The earlier uniface version of these biface projectile points preceded them in time of arrival in Australia. Still earlier in time were the Eastern Mousterian-like blade forms of the Tartangan Culture which must have come out of Asia into the Australian area long before the end of the Pleistocene.

It will not be easy to dismiss consideration of these implement types when the history of modern man is being reconstructed. Absolute dates of their successive arrivals in these peripheral areas

are sufficiently early to suggest that they may have begun their southeastward journeys even prior to times suggested for their appearance on the western fringes of the *Homo sapiens* homeland. It could be that Bushnell and McBurney have been over-cavalier in their treatment of the Chopper-chopping-tool cultures of the East, whose influences loom very large in the eyes of those who direct their attention to southeastern Asia. Writers of a past generation have tended perhaps to dismiss the main Australian stone implement series as "Proto-Neolithic," or "Epi-Palaeolithic," which they are not, and so have failed to take into consideration the rich harvest of information, which the study of them as contemporary survivals, can yield. Now that we have archaeological dates, their place in pre-history must be considered in earnest if valid conclusions are to be reached about the beginnings of the cultures of modern man.

FOOTNOTES

[1]Wormington, H. M. 1957. *Ancient Man in North America.* Denver Museum of Natural History, 4th edition.

[2]Tindale, N. B. 1957. "Culture Succession in Southeastern Australia from Late Pleistocene to the Present." *Records of the South Australian Museum* (Adelaide), 12:pp. 1-49.

[3]Harrisson, T. 1957. "Great Cave of Niah." *Man* (London), 57:pp. 161-166 (c14 date. 32630±700 B.P. [1957 Gröningen]; see also *Antiquity,* 32, 1958, p. 194 for 39600±1000 B.P. Carbon date).

[4]Maringer, J. 1957. "Some Stone Tools of Early Hoabinhian Type from Central Japan." *Man,* 57:pp. 1-4.

[5]Birdsell, J. B. 1957. "Some Population Problems Involving Pleistocene Man." *Cold Spring Harbor Symposia on Quantitive Biology,* 22:pp. 47-69.

[6]Mewhinney, H. 1957. *A Manual for Neanderthals* (Austin: University of Texas Press). Chard, C. S. 1959. "New World Origins, a Reappraisal." *Antiquity,* 33:pp. 44-49.

[7]Lawrence, W. L. 1873. *Proc. Soc. Antiquaries of London,* ser. 2, 6:p. 14 and plate 3.

[8]Ibarra Grasso. 1951. *Ciencia Nueva Revista de Ethnologia* e *Arqueologia. Tucuman,* II, v. 1, no. 3:pp. 56-67, fig. 1-12.

[9]H. M. Wormington, Curator of Anthropology at the Denver Museum of Natural History, has some new opinions on these questions as a result of her recent visit—the first made by an American—to the Siberian collections.

[10]Loewenstein, J. 1958. "Eskimo *ulu* in the Malayan Neolithic." *Man,* 58: pp. 37-41.

[11]Tindale, N. B. 1940. "Distribution of Australian Tribes." *Trans. Royal Society of South Australia.*

[12]Birdsell, J. B. 1958. "On Population Structure in Generalized Hunting and Collecting Populations." *Evolution,* 12 (2) :pp. 189-205.

[13]Tindale, N. B. 1953. "Tribal and Intertribal Marriage Among the Australian Aborigines." *Human Biology,* 25 (3) :pp. 169-190.

[14]Bushnell, G., and McBurney, C. 1959. "New World Origins Seen from the Old World." *Antiquity,* 33 (130) :pp. 93-101.

THE LOT

By A. Kirby Congdon

We walked our parallels
in trolley tracks through wood
where rails unwound in weeds
and rusty goldenrod.
Yellow, shattering tree trunk shadows,
flashed in the far electric hum.

Fountains of gladioli rose to my father's hand,
his shoulders brown above the prim-leaved plants.
His hat, a worn-out sun, hid his head,
his mouth, past pain or praise.
On that hot day, one comfort came:
water, wet and tinted green in jugs
propped in jungles of honeysuckle caves.
The first drops bounced in dust
of that summer day's-end rain
before the long hike back
to the streets of town
and the poplar's thin shade.

The rails were steel and straight.
Clouds had curdled before the storm.
Evening was gray, grave.

Men don't bite dogs

HERBERT BRUCKER

Ralph Crosman served the press by being its conscience. And the first count in his 1946 indictment of newspapers and newspapermen was this: "We are failing to give the people the information they need regarding social, economic, and political conditions to enable them to vote intelligently."

Now I would bring exactly the same indictment. And I think the chief reason why we journalists still fail to give the people the information they need is that we are serving up the news of 1960 in a style suited to 1920. Why should this be? Newspaper people like Ralph Crosman have been saying for a generation what I shall say in this article. Everybody talks about modernizing the press, but nobody does much about it.

Perhaps one reason can be found in what Jack Knight of the Knight Newspapers reports that the late Charles F. Kettering once said to him: "If you fellows would devote as much time to research as you do to protecting a free press, newspaper technology might catch up with the times." But I insist that more than the mechanics of printing newspapers is behind the times; our editorial mechanics are also anachronisms.

If printing technology had by now caught up with the times we would be out of the cost squeeze. And then we would have more money and time and energy to use in bringing newspaper editorial methods up to date. But most of us can do little to increase the productive efficiency of newspaper printing. We shall have to wait until the publishers, the scientists, and the engineers develop some cheaper and easier way than our 1896 mechanics to get words out of the typewriter and onto the reader's doorstep. Even so I insist that there is a lot we could do right now that we are not doing to increase the productive efficiency of editorial methods. It doesn't cost much to summon up enough spirit and enough imagination to get out of a rut.

I am aware that there have been a few minor changes over the

years. We have increased the size of body type, gone in for a bit of horizontal makeup, and learned to use a few more pictures. We have also, relatively at least, shrunk the size of the news hole in our papers. And it is in that hole that we have to do our job. Maybe the cost squeeze leaves no alternative to allotting only a small space for news. But is that any reason why, in the space available, we should still write our stories and display them as though there were no such thing as radio and TV, as though nothing had happened since Woodrow Wilson died?

The results of doing so little to change our editorial and news writing techniques are not good. It should have therapeutic value for us to rub our noses again and again into such readership studies as have been made. Consider the Advertising Research Foundation's Continuing Study of Newspaper Reading. This is a summary of what the subscribers of 138 different dailies of various sizes in various places actually read in specific issues of those papers, as revealed in a reliable, door-to-door study made over the years between 1939 and 1950. The basic idea was to show that the people do read papers—and read the advertising in them. Thank God it did show that. It also showed good readership in such peripheral fields as pictures, comics, society news, and sports. But it revealed a real shocker at the heart of things: namely, that of the nearly 18,000 general news stories published in those 138 daily newspapers men had read only 14 percent, and women only 11 percent.

There seems to be only one explanation: People aren't interested in news. Or is there, perhaps, another: that people *are* interested in the news, but are not interested in it in the form in which newspapers present it? This reminds me of a line in a little book I published twenty-two years ago, *The Changing American Newspaper*. In speaking of the fact that already in those depression years news had acquired more depth than our reporting traditions could cope with, I quoted a line from a play of the times, "Clear All Wires" by Sam and Bella Spewack. In it a World War I type of sensation-seeking hero reporter was told by a more modern, essayist type, "People aren't interested in news any more. They want to know what's happening."

The fact that we do not tell enough about what is happening is,

I submit, the reason why our news does not get better readership than it does, why the cost squeeze pinches as sharply as it does, and why we are often uneasy about the job we are doing, and the future of the newspaper.

How can we give flesh and blood to a new concept of news? I think only by starting all over again, by thinking afresh as though the newspaper were being invented for the first time today. It must be a paper that fits naturally into a world of soap opera and "Gunsmoke" and Dave Garroway, of jet planes, Khrushchevs, moonshots, and electronic brains. Ours is, moreover, a world in which it is every American's birthright to have his own automobile, and to go out in it when he ought to be home reading his newspaper.

I rather think that much of what needs to be done has already been done—here and there. It is nothing revolutionary, just common sense. But instead of regarding these new methods as isolated curiosities, we ought to make them the models of all we do. I should like to examine a few of these ideas and experiments. Specifically, I suggest that we must do these things: 1) re-define news; 2) search out the new kinds of things people are interested in, and print them; 3) rethink our concepts of what space a particular item is worth; 4) scrap our formula for writing news in favor of one suited to 1960; 5) find ways of organizing and displaying the news that are suited to today's needs.

Let us look into each of these possibilities. First, what is news? If any one thing can stand as symbol of our difficulties, it is our basic assumption as to what news is. Hence the title I have chosen for this essay, "Men Don't Bite Dogs." You all remember I am sure the classic definition of news, the one usually attributed to Charles A. Dana of the *Sun* but apparently actually originated by Dana's city editor, John T. Bogart, in 1880. It is this: "When a dog bites a man, that's not news, but when a man bites a dog, that's news." In other words, news is the unusual, the unexpected, the spectacular. And that is still true, as far as it goes. But does it go far in the life of the 1960 newspaper reader? Why should he get excited if his paper tells him that a man did bite a dog—when radio or TV

have already told him about it before he even gets his paper? Why then should we write and display the news in ritualistic obeisance to this Victorian heirloom, this 80-year-old idea that only the spectacular, the novel, or the bizarre are news, as though Moses had brought it down from Sinai and nothing had changed since?

Turner Catledge, managing editor of the *New York Times,* has a definition of news more suited to 1960 than the 1880 version: "News is anything you find out today that you didn't know before." There is a lot that today's newspaper can tell its readers that they didn't know before, beside the fact that Joseph K. Blow, 39, of 2478 Maple Street, bit a dog yesterday.

First, though, there is some dead wood that we ought to get rid of. I nominate as first candidate for the scrap heap that phony, the overnight lead. We are all familiar with the fact that of our 1,751 daily newspapers only 307 are morning papers. In the nature of things morning papers have the time to collect the day's news and present it in ordered fashion. They tend to be the ones with prestige, the ones that set the standard despite their small numbers. Besides, it often happens that what is in the morning headlines has already been broadcast the evening before. Inevitably the evening papers must still sell essentially the news of what happened yesterday. In this fix our fetish that news is novelty impels us to invent for the 1,456 evening papers an overnight lead that looks new even if it isn't new. So it is that our local reporters and our wire-service men alike scratch their heads to get a new lead that, synthetic though it usually is, seems to be newer than the one that has already appeared in the morning papers.

Do we really have to telephone around to needle some local politician or some Washington bureaucrat or Senator into expressing a reaction to something that has happened today, so that when the wire services get to clacking early in the morning, or when we sit down at night to write a little piece that is not going to be published until noon the next day, we shall have something that qualifies as news by the man-bite-dog standard?

Again, the results are not good. I quote from a letter an able but frustrated Congressman wrote me recently:

> Here in Washington I have been impressed with another variation of newspaper business, and that is the reluctance of even the best news-

papers, such as the *New York Times* and the *Washington Post,* to pick up a story that lacks the drama of a personal attack or some extreme slant.

Clair Engle of California, for instance, spent weeks preparing a speech for the Senate floor on what was wrong with our China policy and why he felt it should be drastically changed. Although this was the first sharp break with the Knowland line in Congress by anyone of stature, neither the *New York Times* nor the *Washington Post* printed a single line of it.

Sitting here in Congress week after week, it is easy to understand why Congressmen and Senators resort more and more to bitter charges and extreme criticism. This is the one sure way they can get publicity. I do not know what can be done about it, but I have a strong feeling that many public figures behave irresponsibly because only by behaving in that way can they make themselves heard.

Perhaps this complaint makes too much of too little. But is there not truth in it? Hopelessly confusing and vast though this world is, what goes on in it is fascinating. There must be some way of reporting it that makes good reading without relying on men who bite dogs. Without a fresh, straightforward way of reporting we often miss the real story.

Sure, conflict still makes news, and so does money, sex, or anything else spectacular or juicy. Sure, lots of people are bored stiff with the complexities of their world that they ought to know about, and flock to the cheapest and most vulgar that TV (or we) can dish up to them. Still, isn't there a little readership to be had, a little money to be made, by ceasing to act as though the important were trivial, and the trivial important?

A few weeks ago *Newsweek,* celebrating Walter Lippmann's seventieth birthday, noted that he hopes to be remembered as one of the early interpretive reporters. It quotes him as saying: "The art of Washington journalism changed with the depression. At the end of the Hoover Administration, and especially in the early Roosevelt days, events started happening which were almost meaningless in themselves. It was the beginning of the era when Why became as important as What, when a Washington correspondent left his job half done if he told only what happened and failed to give the reasons and hint at the significance."

There is another reason beside the increasing complexity of public affairs that makes the Why more meaningful to newspapers

than the remaining trio of the classic Four W's, What and Where and When. This is the coming of radio and TV. What a change electronic journalism should have forced upon us was borne in on me some years ago, when one night I emerged weary and worn from a session of the 1952 Republican National convention in a sweltering Chicago. This was the first national convention to be given saturation coverage by television. And it soon became obvious that TV's eyewitness reporting of at least such great public events would henceforth do a good part of the job that in the past had always been done by newspapers. Remember, for example, Mr. Khrushchev's recent barnstorming tour of this country. Just so at that convention one particular incident drove home the meaning of this change to me. There was a dramatic moment when Senator Dirksen, from the klieg-lighted rostrum, had pointed a finger of scorn at Governor Dewey. What was the point in the millions of words filed from the convention hall that day to report this fact as news, when for all practical purposes the whole country had seen it happen?

We have of course had radio coverage of national political conventions ever since 1924. Gaffers like me remember that famous radio refrain from the deadlocked Democratic convention in New York that year: "Alabama, twenty-four votes for Oscar Underwood!" Perhaps we should have changed, or at least begun to change, our method of reporting at that time. Certainly it is high time that we should now.

I want to be clear. We all know that the person who has been at the ball game, or has been present at a great event via radio or TV, is the best customer for the newspaper's ordered account of what really happened. On top of that we obviously must go right on getting and printing the hard core of news just as always. We cannot be sure that every reader has been in faithful attendance at the loudspeaker or TV screen. There remains also that fundamental merit of the newspaper that it provides a permanent record, one that the citizen can pick up and read at any time, and keep to consult again another day if need be. Finally, we have the supreme advantage that the reader can select at will from a vastly varied bill of fare in the newspaper, while on radio or TV he has to take all or nothing.

Even so the point remains: It is high time we changed our methods of reporting, to suit them to readers who have access to radio and TV. Don't forget that in 1957 the number of homes with TV sets for the first time outnumbered those receiving a daily paper. And for some years before that homes with radio outnumbered homes with daily papers.

If we could recover some of our youth, even some of our naivete, maybe we would not dismiss as un-newsworthy a multitude of events and activities that the customers find absorbing when they do see them in print. The *New Yorker* has been taking apart the obvious for a generation, and in so doing has come up with fascinating fact-stories that the newspapers have missed. Newspapers do it too—occasionally. For example last year the *New York Times* presented a behind-the-scenes account of how New York's Board of Elections prepares for election day. Under our 1880 formula as to what news is, only the election itself, or what a candidate or other big shot says about it, qualifies as news. But here was a graphic account, in words and pictures, that told all about an important part of political life that most newspapers take for granted and so ignore. It made fascinating reading.

Then again, those of you who read the *Wall Street Journal* know that on its front page every day, in the leading news-story positions, there are three stories that often, according to journalistic folklore, are not news stories at all. They belong in that second-grade category, feature stories. Or do they? Actually they are detailed, readable, authoritative news roundups based on extensive fact-gathering. They will tell you anything from what the 1960 cars will look like and be like—in advance of the official release date—to a fascinating account in personalized, pictorial terms of how department stores recovered this year from last year's slump. And when you have read one of these accounts you feel you know all about its subject. These are, if you will, magazine articles. But like much else in the magazines themselves, and even some books nowadays, they do a more adult job of reporting than we do most of the time.

The truth is that man is doing a lot of meaningful things, and that a lot of other meaningful things are happening to him that he does not understand. He likes to read about both, even though

neither qualifies as man-bites-dog news. This means that we can find good material not only by reporting the normal headline events in depth, but also by developing fresh sources of news in what we now overlook. Let me remind you that two years ago, at the ASNE convention in San Francisco, Dr. Gallup reported that newspapers were not publishing a lot of the things that his studies revealed their readers to be most interested in. Among these were: health and related matters of medical science and practice; education; religion; financial problems of the people; what people think; and people in the news.

Some might fear that to put skilled writers to producing magazine-type articles in such fields would be too costly for all but big-city newspapers. But earlier this year there appeared, at a new-writing clinic sponsored by the University of Illinois School of Journalism and the Illinois Press Association, the managing editor of a weekly newspaper in the Chicago area. He was Charles Hayes of Arlington Heights, and he declared that editors of small papers are wrong when they say that reporting in depth is beyond their resources. And he cited chapter and verse from his own experience:

> We have stimulated community concern for approaching problems in crime, health, delinquency, poverty, and prejudice as our area continues to make the transition from country village to city. The area has responded to this need.
>
> We have assigned reporters to dig into problems of hodge-podge development, traffic congestion, poor drainage, slums, sewage trouble, crowded schools, under-staffed public offices, police, fire, and sanitation emergencies. . . .
>
> We applied this policy of depth reporting to religious news and have attempted to present better interpretation of the affairs of the church and to educate the public on the nature and implications of expanding religious life.

I realize that much of what I am urging gets into interpretive reporting. And some among us fear interpretive reporting, on the ground that it contaminates that greatest achievement of American journalism, reporting facts without bias. Actually, though, interpretive reporting does no such thing. It is just reporting suited to the complexity of today's world, and is not a license to express opinion.

It is regrettably true that many of our by-line reporters actually do write editorials in the guise of explaining the news. And the line between the two is fuzzy. But I insist that there is a simple test that distinguishes interpretive reporting from editorializing. Is the reporter digging up the truth in the dispassionate spirit of the scientist? Is he honestly collecting all the evidence he can on *both* sides of the argument? Or is he arguing a case, plugging some particular point of view? The one is just good reporting, in modern dress. The other may be good, too, but it is writing editorials and not reporting.

By using interpretive reporting, indeed, a newspaper can achieve objectivity rather than depart from it. And it is not only here in Colorado that one remembers the instruction Palmer Hoyt issued to the *Denver Post*'s staff six and a half years ago to preserve objectivity against the rising tide of McCarthyism. He sought in various ways to set the almost daily McCarthy blasts into the perspective of related facts right at the time of first publication. Surely this was more objective reporting than is the inherited brand, which Elmer Davis used to denounce as deadpan reporting—the publication of a suspected or unknown lie without qualification, just because a noise-making Senator issued it from behind Congressional immunity.

Let's sum it all up this way: We still have to print a certain amount of jazz and guff and corn, to suit enough of the customers. But for the most part we can leave the trivial, the froth, and the vulgar to the mechanized show business that is radio and television, while we return to the news itself. We can find the news as it is today in this crazy, mixed-up world, if only we have the wit and the will.

So much for redefining news. Next on my list of things to do is rethinking our standard of what space a given item of news is worth. Here, too, we ought to scrap our traditions and look at news values as though for the first time. For a generation now *Time* has been showing us how to condense, but we have not taken the hint. Here is what *Time* said earlier this year in hardly more than an inch of large, readable type:

A mite miffed when woolly-mopped pianist Van Cliburn begged out from their ceremonial dinner (reason: a prior engagement), the U. S.

Junior Chamber of Commerce brooded once more, decided that Prodigy Van was not really one of the nation's ten outstanding young men of 1958 after all, instead named fresh-faced Crooner Pat Boone.

The Associated Press account, gold standard of orthodox news writing, took 8½ inches of small newspaper type to tell the same story.

Maybe then it would be worth a little time and money to compress standard news into paragraphs that pack a punch, and to use the space thus saved—there would be an enormous amount of it—for detailed, readable stories about the new kinds of news that Dr. Gallup prescribes.

One paper, at least, has already done it. I refer again to the *Wall Street Journal.* Back in 1934 it launched twin columns headed "What's News—" that appear on page one every day. One column summarizes business and finance, the other the general news, mostly national and foreign. Both let the reader find out effortlessly and in incredibly brief space the essentials of what has happened. And if he wants more about some of the big stories of the moment—say what Premier Khrushchev had done the day before in San Francisco and Des Moines—he can find it all inside.

Maybe such condensation is too stiff for the general newspaper. But still, is it necessary for us to give routine stories all the space we do? There is no question that for the specialist the detailed coverage that reaches its peak in the *New York Times* is infinitely precious. But for the busy ordinary Joe and his wife, it can be overwhelming.

Next after space on my list is the style in which we write the news. Why, for example, do we still slavishly fit news into the inverted-pyramid formula? Those of you who may not be in our trade should know that the inverted pyramid is a Procrustean bed to which we adapt all news stories. The formula is to hit the reader between the eyes, bing-bang-biff, with the essentials of the whole story, in the least possible space. Thus we give the reader all he needs in the first paragraph or two. Then, if by some chance he is still interested, he can in the succeeding half-dozen paragraphs sample an expanded version of the same information, together with a few new facts. Next, if he is still with us, he can

jump over to a back page, where the tale gradually gets less and less interesting, until finally it peters out in sheer insignificance.

This literary strait jacket was developed for good and sufficient reasons between the Civil War and World War I. In those days, when nobody had any way to get news but from a newspaper, the inverted pyramid was fine. It made it possible to present a lot of news about the growing, bustling United States by offering it all according to a formula that let the reader sample any story that struck his eye or his fancy. For the first time he didn't have to read everything in a newspaper of growing bulk. But the technique has had the effect of lessening the drama in an individual tale, and has encouraged the reader to pass on to the next item after a paragraph or two, secure in the knowledge that he knows the essentials of the event already.

In today's world of complexity, radio, and TV this formula has only partial validity. Urs Schwartz, foreign editor of Switzerland's *Neue Zurcher Zeitung,* recently summed up its present state in these words: "The thoughtless inversion of a story, confusing the reader, involving repetition, obscuring the course of events and the relationship between cause and effect, is now out of date." Why don't we do what Louis Lyons, Curator of the Nieman Fellows, recommends: Write the news according to the simple formula of the Queen in *Alice in Wonderland,* which is to "begin at the beginning and go on to the end."

There remains one more suggestion in this prescription for preparing the newspaper for 1960: departmentalization. Now a generation ago there was vast enthusiasm over doing in newspapers what *Time* had taught us could be done in the way of segregating news into categories. But those who tried it learned that it just is not practical, in the hurly-burly of getting out a daily newspaper, to sort the news into that many compartments. So that was that. But must we therefore throw at the reader the undigestible, disorganized hodge-podge we give him every day? The *New York Times,* again, does an admirable job of collecting all on one page or set of pages everything it finds fit to print in the foreign, state, local, and other kinds of news—just as we all do with a few stock items like sports or comics or women's news. There seems little reason why even the smallest papers cannot do

something like what the *New York Times* does. The medium-sized St. Petersburg *Times* in Florida, for one, does an excellent job of it. And Tom C. Harris, executive editor, notes that while in 1933 his paper did not have even 12,000 subscribers, it has 100,000 today. He admits that the phenomenal growth of Florida is largely responsible. But, he says, the paper's editors know "that departmentalization of news has played a big part, too," in building the paper. Again it seems to me less an inherent difficulty that stops departmentalization than lack of enough energy to try it.

So at last I come to the end of my tale. In urging that we cease looking for men who bite dogs, and instead look into what is biting men, I have dealt largely with editorial concepts and practices. I am certain that, if we explore the possibilities already at hand with thought and enthusiasm, we shall be rewarded with more of the time of those readers we already have, and shall win new readers as well. The successful examples before us hint at what can be. Note that the *Wall Street Journal*, under its modernization program, has shot up from a circulation of 32,500 in 1940 to 620,000 now.

But are changes in formula enough? I do not think so. One of the reasons why we honor Ralph Crosman is that he was concerned not only with the technical excellence of newspapers, but also with their moral purpose and courage. While we wait for the increase in productive mechanical efficiency that can make journalism over, while we busy ourselves with modernizing our 60-to-80-year-old editorial methods, we can if we will also recapture something of the dedication to ideals, even at what may on the surface seem like financial risk, that made the great editors and publishers of the past. We can resolve that the only sacred cow we shall respect is the truth, as best we can find it out. And we can search it out, whether behind the closed doors of government or in those fascinating eddies in the stream of events we neglect today.

If we do this, we shall be doing something far more useful to honor courageous pioneers of journalism like Ralph Crosman than just talking. We shall be living the ideals for our profession that he and his like bequeathed to us.

The inverse square law in physics

WILLIS E. LAMB, JR.

My title was chosen with the varied interests of a general audience in mind. It provides me with an opportunity to present historical material from the time of Newton as well as problems of interest in contemporary physics. Moreover this topic gives a good example of the way in which physical science develops with the help of experiment, imagination, and mathematical analysis.

As you know, there is nowadays an obvious need for better education in science, particularly for non-specialists, and there is considerable discussion of methods for achieving this. Some would teach case histories of scientific discoveries of several hundred years ago to illustrate methods which may not be very useful today. Others would try to give only an account of the most recent developments. I would somewhat prefer a combination of the two methods, in which the historical development is traced up to the present time.

On one point, however, I have strong views: Anybody who is taught anything in school should learn enough mathematics for the expression of simple ideas in mathematical language. The percentage of mathematical illiterates should be no higher than that of any other kind. Children who learn mathematics early can make a useful transition from arts to scientific studies even after they enter the university. For this to be possible, better methods of teaching mathematics must no doubt be developed. In the meantime, parents should stop telling their children that mathematics is difficult and that they themselves could never understand it. We all know the sort of man who never understood "figures" but who has made enough money to be able to hire the services of as many accountants as he needs to prepare his income tax returns. I would like to suggest that he should refrain from bragging of his ignorance.

Now I shall begin with a general discussion of laws in physics. First of all: What is a physical law? Examples are easy to give:

Newton's laws of motion, Snell's law in optics, Boyle's law for gases, Hooke's law for stretched springs, Ohm's law in electricity, and the laws of conservation of energy, momentum, and parity. In each case the law makes a statement about physical quantities, and presumably can be tested with more or less precision by laboratory experiments. Some of the laws I mentioned are only useful approximations which describe phenomena of great complexity, but of very little fundamental significance. It sometimes happens that a physical law which seems very fundamental at one epoch of science may later be reduced to a trivial consequence of a more fundamental law. Thus Hooke's law that the stretch of a spring is proportional to the force applied to it follows in principle from the laws of a more fundamental theory called quantum mechanics applied to the atoms which constitute the spring. Owing to mathematical and physical complications, the calculation cannot actually be carried out very accurately for a real spring, but most physicists would consider that the fundamental tools are available for an understanding of Hooke's law.

Other physical laws are believed to have a much more fundamental importance, for example, the laws of conservation of energy and momentum. These laws have survived several challenges to their validity by the discovery of new forms of energy and momentum, such as the energies associated with heat, radiation, and mass. In the formal theory, the laws of conservation of energy and momentum are reduced to a statement that space and time are intrinsically homogeneous. This means that the basic physical laws should not treat one part of the universe differently from another. The results of an experiment may nevertheless depend on the presence or absence of nearby matter, for example, the earth or a magnet.

Then there is the law of parity conservation which states that the basic physical laws should not distinguish between right- and left-handedness. Of course, man-made laws do distinguish between the two. In most countries automobiles are legally driven only on the right-hand side of the road, although the reverse is true in Great Britain and in Sweden. Presumably these practices should be regarded as historical accidents and are not required by any fundamental laws of nature. Two years ago, however, it was

found by Yang and Lee that this law of right-left symmetry is not valid for some very weak interactions involving nuclei and elementary particles, although it continues to have great accuracy for most physical phenomena.

Now from this brief discussion of physical laws in general, let us turn to the inverse square law. This law appears in several apparently different branches of physics. Sometimes it seems to be only an expression of a simple geometrical fact. Consider a circle of radius r. Its circumference is a little more than six times its radius. If we double the radius, the circumference of the circle also doubles. Consider instead a sphere, which might be approximately obtained by inflating a toy balloon. The area of the surface varies as the square or second power of the radius. When the radius is doubled the area increases fourfold. If space had four dimensions, the area of the "surface" analogous to the spherical surface would increase as the cube or third power of the radius, and faster still if space had more dimensions than four. Many philosophers and scientists, from Aristotle through Eddington, have attempted to find a "reason" for the three dimensionality of space, but without much success.

Thus, in his *de Caelo,* Aristotle says all things are determined by the number three since everything has beginning and middle and end. This argument for the three dimensionality of space was ridiculed by Galileo Galilei in his *Discourses.* Emmanuel Kant thought that if there were more than three dimensions God would have made use of them. The German mathematician Gauss considered that the three dimensionality was not an inherent quality of space, but a specific peculiarity of the human soul. He also sought to deduce it from the inverse square law of gravitation, but as we will see, this is probably putting the cart before the horse. The French mathematician Poincaré's speculations on this problem were not very fruitful for physics although they led to the development of a branch of abstract mathematics called dimension theory. In 1917, the Dutch physicist Ehrenfest pointed out some interesting ways in which physical phenomena would depend on the dimensionality of space. For example, the orbits of planets about the sun would not be stable in a world of more than three dimensions.

No doubt you have heard that space and time are sometimes united to give four dimensions. This has certain convenience in mathematical physics, but should not be allowed to shake our confidence in the actual three dimensionality of space. Perhaps the best reason we can give for the number three is that life in a one or two dimensional world would be too simple to be interesting and in a four dimensional one too complicated.

The above mentioned property of three dimensional space, that the area of a sphere varies as the square of the radius, has some important physical consequences. Consider a source of light, such as an electric light bulb suspended somehow in a large empty region. For simplicity we imagine that the lamp can be considered as a point source which sends out its light, or radiant energy, uniformly in all directions. It does not matter whether we picture the light as composed of particles or waves.

Let us follow this energy as it passes through a succession of imaginary spherical surfaces centered on the lamp. If we assume that energy is conserved, i.e., not lost as it might be if absorbers were present, the amount of luminous energy passing through a square foot of spherical surface, which we call intensity, will decrease with increasing radius; in fact, the intensity will vary inversely as the square of the radius. If we double the distance, we get one quarter as much intensity.

We have here an example of the inverse square law: In photometry the intensity varies inversely as the square of the distance from the source. To test this statement experimentally, we might use a photoelectric exposure meter as in photography. To get good results we would have to use a sufficiently small source and avoid obvious complications due to other nearby lights, reflectors, or absorbers. If space had a different number of dimensions than three, the inverse square law of photometry would be changed. For example, if there were just two dimensions, the intensity of light would only vary inversely with the distance and not inversely with the square of the distance. This might be simulated if the lamp were screened so that it could only emit light uniformly in a plane instead of into all directions in space. Incidentally, the same variation of intensity with the inverse first power of the distance would also be found if the lamp were a very long thin

flourescent tube. To summarize, we may say that the inverse square law for light intensity expresses the three dimensional character of space plus the law of conservation of radiant energy.

Although we assumed the lamp to be a point source, we are able to consider actual lamps by applying the inverse square law to small bits of the luminous material and adding their effects. When we later discuss the inverse square laws of gravitation and electricity, we can make similar statements if we have extended distributions of matter or electricity.

I might point out that the inverse square law for light has far reaching consequences for astronomy. According to a plausible hypothesis which is popular with astronomers, stars are distributed uniformly throughout all of space if we neglect local fluctuations such as star clusters, galaxies, and families of galaxies. For simplicity, let us pretend that all stars are just like our sun, except for their distance from us. When we go out-of-doors on a clear night we would expect to see the nearby stars as bright ones and the distant stars more faintly because of the inverse square law for light intensity. However, the total number of stars per unit distance from us increases as the square of the distance. The faint stars are more numerous than the bright ones in just such a way that the whole sky should be as bright as the sun's disk. The total light would be that of about 100,000 suns, in flagrant disagreement with observations. This is called Olbers' Paradox, and dates from the 1820's. Modern astronomers avoid this difficulty by considering that very distant stars are receding from us so rapidly that their light is unable to reach us with the intensity assumed in the previous argument.

We now turn to a discussion of several inverse square laws of force. For our purposes, it will suffice to picture force as a push or a pull which we might exert on an object by muscular action. We should have some intuitive idea of what it means to exert half as much or double a given force. Note that actual contact seems to be essential for the application of such a force.

Now, historically, the development of the physical laws of force could only proceed with simultaneous advances in the science of mechanics. I shall assume that we know all about mechanics as developed by the experiments of Galileo and embodied in the laws

of Newton. We need to know that if a solid object is undisturbed by applied forces it will remain at rest if it is initially at rest or will continue to move uniformly if it is in motion. If there is a net force acting on the body, it will change its velocity, or accelerate, at a rate proportional to the force and inversely proportional to a measure of the quantity of matter in the body which is called its mass.

In present day physical theory there are four kinds of forces or interactions: (1) gravitational forces; (2) so-called weak interactions, which are responsible for some kinds of radioactivity; (3) electromagnetic forces; (4) nuclear forces, or so-called strong interactions. I have arranged these forces in order of increasing strength, as measured in a way which makes sense to physicists. In our everyday life we are most easily aware of the first named force of gravity. When we fall off a cliff we might not think the forces involved are the weakest ones known, but the mass of the earth is very large and this confuses us.

Many physicists feel that four kinds of forces are too many and are attempting to reduce the number. In the historical development, many more forces than four have been considered. Thus electrical and magnetic forces are no longer treated separately as they had to be before 1820 but are brought together as different manifestations of electromagnetic action. With modern developments in atomic theory it is possible to consider the forces which hold ordinary matter together to be of electromagnetic origin. The properties of atoms, molecules, gases, liquids, and solids are to be explained in terms of electromagnetic interactions, apart from gravitational forces acting on massive systems and minute effects arising from the atomic nuclei.

There are many interactions of great practical importance which modern physics reduces to electromagnetic forces. Consider for example what happens when two very highly polished metal blocks are pushed into close sliding contact. They are found to be held together very strongly. One speaks of a force of cohesion which has a range of action not more than a millionth of an inch. There are also important short range forces which give steel beams their strength and allow springs to be stretched. Further examples of electromagnetic interaction between atoms are capillary forces

which cause drops of rain to form, pneumatic forces which inflate tires, aerodynamic forces which make it possible for birds to fly, and chemical forces which make gun powder explode.

In the eighteenth century, a Serbian physicist priest named Boscovitch tried to find a universal law of force which would account for all known interactions. Needless to say, since he had no adequate theory or knowledge of atomic structure, his force law had to be unmanageably complicated. As I stated before, all of the just mentioned forces, and many more, are now regarded as manifestations of the much simpler electromagnetic forces applied to systems of electrons and atomic nuclei which obey the laws of quantum mechanics.

I mentioned the four kinds of force which are considered in present day physics. Of these, the weak and strong interactions are "short range" forces and can act only over exceedingly small distances of the order of a millionth of a millionth of an inch. On the other hand, both gravitation and electromagnetic forces can cause effects over considerable distances. We consider first the case of gravitation.

Newton showed that if he assumed a law of attraction between all masses which varied inversely as the square of the distances between them, he could explain both the way in which a stone falls on the earth a distance of sixteen feet in the first second and the way in which the moon moves in a (roughly) circular orbit about the earth with a period of twenty-eight days. The moon is caused to move in a circular orbit by the gravitational pull of the earth, much as we can make an object move in a circle if we swing it about us on a string. The tension in the string in the latter case corresponds to the force of gravity in the former. In order to get the right relationship between the sixteen feet for the stone and the twenty-eight days for the moon, Newton had to assume the inverse square law for the gravitational force. The fact that the earth and moon are not mathematical points caused him some trouble and might have delayed his publication for twenty years until he developed the necessary mathematical methods which now comprise integral calculus.

We do not know to what extent Newton first arrived at the inverse square law from geometrical considerations involving the

three dimensional character of space analogous to those which we used for light intensity. If the force between the sun and a planet were an interaction specific to those two bodies, one would have difficulty in guessing how the forces depended on the distance. Kepler had pictured the force as being spread out uniformly into the plane of the orbit, and so was led to expect a force varying inversely as the first power of the distance. With the subsequent advances in mechanics and the recognition that gravitation was a universal force, it became much more reasonable to think of the gravitational attraction as due to a force field reaching out uniformly in all directions from each attracting body. Several contemporaries of Newton, among them Robert Hooke and Sir Christopher Wren, had guessed the correct form of the force law before Newton proved it, and were in part guided by such geometrical considerations.

The Newtonian theory has now been very well tested by application to the objects of the solar system. Because of the many bodies involved, the problem has considerable mathematical complexity, and has received contributions from many eminent mathematical astronomers. The agreement between observations and calculations is at present very satisfactory. With the launching of artificial satellites there has been a recent revival of interest in celestial mechanics.

Early in the nineteenth century it was noted that the orbit of the newly discovered planet Uranus was not quite in agreement with calculations. This led to the prediction and finding of another planet called Neptune in 1846. Similarly, from small irregularities in the motion of the outer planets, Percival Lowell predicted an even more distant planet which was found in 1930 and named Pluto.

About a century ago, similar anomalies in the motion of the innermost planet Mercury were found. The motion of Mercury is predominently due to its gravitational attraction by the sun. According to Newtonian theory with the inverse square law of force the orbit should then be an ellipse with orientation fixed in space. It was found however that the ellipse turned around at the very small rate of a sixth of a degree per century. Most of this motion could be attributed to the perturbing effect of the other

known planets, but there was a residual drift of about one-eightieth of a degree per century which remained unexplained. About 1850, the French astronomer Leverrier, who had predicted the location of Neptune, made a hypothesis that the motion was due to the presence of a new planet between Mercury and the sun. In fact, for a time, people thought that such a planet had been seen, and it was called Vulcan after the god of fire. Unfortunately, however, what was thought to be a new planet crossing the sun's disk was in fact a sun spot.

Another attempt to explain the anomaly was made around 1890 by the American astronomer Asaph Hall. He pointed out that if the law of gravitational attraction were not exactly an inverse square one the elliptical orbits would precess around slowly. Hall found that by increasing the exponent two of the inverse square relation by a few parts in ten million, the motion of Mercury could be explained without upsetting the very good agreement with the outer planets. This would mean that, if the distance were doubled, the force would be divided by slightly more than a factor four. However, Hall's suggestion had later to be rejected because it led to disagreement when applied to the motion of the moon about the earth.

In 1916, Einstein in his General Theory of Relativity found an extension of gravitational theory which applied to rapidly moving masses. The above mentioned discrepancy for the planet Mercury was explained within the accuracy of the observations. At the present time, one can say that the exponent two of the inverse square law of gravitation when applied to the solar system could not differ from two by more than a few parts in a billion. There is some evidence, although of much lower precision, that the law is valid over distances involved in galaxies, perhaps a hundred million times the radius of the solar system.

Gravitation was considered by Newton to be a force which acted at a distance across empty space. In Einstein's theory, the intervening space is also empty, but it has curvature. In both theories, there is a mathematical connection between the validity of the inverse square law and the three dimensionality of space, although not one of such an intuitive nature as we had for the inverse square law of photometry. There is some speculation that a future theory

will make use of an elusive particle of nuclear physics called the neutrino to provide a carrier for the gravitational attraction, in which case there may be a more obvious connection with the dimensionality of space.

We now turn to electromagnetism. Electricity has been known since ancient times, and you are all familiar with some of its properties. For example, if you comb your hair on a dry day, the comb will attract bits of paper because it acquires an electrical charge. Magnetism, also known to the Greeks, according to present theory involves electric charges in motion. For simplicity, I will consider only electric effects.

In the eighteenth century the physicists Cavendish and Coulomb found that electrically charged bodies exerted forces on each other which varied roughly with the inverse square of the distance. While gravitational forces are always attractive, electrical charges can be either positive or negative. Like charges repel one another, and unlike charges attract one another. In many situations atoms are electrically neutral, and the forces between them are greatly reduced. The numerous short range interactions which I mentioned earlier are the residual consequences of mutual atomic distortions.

We study gravitational forces using the solar system. For the precise study of electrical forces we have nothing available on so grand a scale. However, there are metallic substances which conduct electricity, and this makes it possible to perform much more delicate laboratory experiments with electrical phenomena than with gravitational ones. Measuring instruments are easily shielded from outside electrical disturbances by surrounding them with a metal envelope. In fact, the very possibility of doing this depends on first, the existence of metallic conductors and second, the exact validity of the inverse square law of force between electrical charges.

In the case of gravity, no conducting or shielding material has ever been found. In fact, we know that there is nothing in the earth which can interfere with gravitational action to any appreciable extent. In the calculation of the orbit of the moon about the earth, the force exerted on the moon by the sun plays an important part. During lunar eclipses, the earth passes between the

sun and the moon. If there were any shielding action by the earth, the motion of the moon would be affected. The accuracy of this test is so high that one can say that the force of gravity is transmitted through the entire earth with a loss of less than one millionth of its strength. Roger Babson, who is famous because he foresaw the 1929 stock market crash, has offered a prize of $1000 for the invention of a gravity shield; but if the whole earth will not suffice, who will win the award?

Returning again to electricity: Experiments on electrical shielding have shown that the exponent two of the inverse square law can be different from two by at most one part in a billion. The distances involved in the experiments of Plimpton and Lawton in 1936 ranged from about an inch to several feet. Incidentally, I should mention that the inverse square law for photometry follows from the laws of electromagnetism.

Electricity and gravitation also differ in respect to "action-at-a-distance." Application of the ideas of quantum mechanics to the electromagnetic field leads to the concept of a particle of zero mass which moves with the velocity of light. This so-called light quantum or "photon" can be emitted by one charge and absorbed by another, thus transmitting a force between the two charges. Many other phenomena of modern physics involve these photons. Nothing useful has come from attempts to apply similar ideas to gravitation.

There is no test of the validity of the inverse square law of electricity over astronomical distances, although Bondi and Lyttleton have recently speculated that electrostatic repulsion between charged galaxies is responsible for the expansion of the universe. However, it is possible to test Coulomb's law with precision even better than one part in a billion right down to atomic dimensions. The simplest atom is the hydrogen atom which consists of two elementary particles, an electron and a proton, which attract each other electrically. According to the theory given by Nils Bohr in 1913, the electron moved about the proton in a circular or elliptical orbit in a way similar to the motion of a planet about the sun. In atomic theory, one is not so much interested in the motion of the electron as in its energy. When various refinements were made in the theory by the introduction of quantum mechanics in 1925

and a proper formulation of its relativistic form by Dirac in 1928, it was found that the energy of two distinct states of motion coincided exactly, or at least they would if the inverse square law of attraction were exactly valid. After the war, it became possible to measure very small atomic energy separations by using the short radio waves developed for radar, and it was found by Retherford and myself that the two states in fact had different energies.

This effect could be attributed to a slight departure from the inverse square law for electrical forces. It is amusing that a change in the exponent two by a few parts in a million would be required—even more than in Hall's discussion of the precession of the orbit of the planet Mercury. Of course, a much better theory of this effect for Mercury was given by Einstein's General Theory of Relativity. However, gravitational interactions are completely negligible in problems of atomic structure, and the explanation of the two separated energy levels of hydrogen had to be sought elsewhere. These observations caused a very intense activity on the part of theoretical physicists and led to the present view that the energy separation is due to a kind of fluctuating quantum mechanical electrical disturbance present even in empty space which exerts forces on the electron and gives rise to this and other observed effects. Taking these corrections into account properly, one may say that the electrical inverse square law is even more valid for atomic distances than for the larger distances mentioned earlier.

Electrical forces are of considerable importance even inside the atomic nucleus, whose dimensions are about ten or a hundred thousand times smaller than those of an atom. The nuclear forces are basically much stronger than electrical forces and are predominantly responsible for the systematics of nuclear structure and the possibility of thermonuclear reactions from which our sun derives its energy. However, a nucleus of an atom such as uranium has a high electrical charge and is unstable with respect to fission into two lighter nuclei. The explosive power of an atomic bomb is really due to electrostatic repulsion between the fission fragments, and this obeys the inverse square law.

It must be said, however, that nuclear forces definitely do not obey the inverse square law but instead have a very short range of

action. This shows that there cannot be a unique connection between the force law and the dimensionality of space. It is really very strange that such a simple force law can be valid with fantastic precision for two of our four forces and not for the other two. According to present views, the short range forces are transmitted by particles called mesons which have a non-vanishing mass. If their masses were zero, the forces would presumably follow inverse square laws. Some properties of the so-called elementary particles and their weak and strong interactions are now known, but many more will have to be determined experimentally before their theoretical interpretation can be given. There is plenty of work for future generations of physicists, and it is certainly too early to attempt to speak the last word about the inverse square law, however accurately we know it to be obeyed.

HERMIT

By William Beyer

Keep the curtain drawn on stars,
That I may never know,
The simple beauty in the way
They twinkle so.

Bolt the sash on Winter moon,
That with a hermit's eye,
I never see the festive way
The snow woods lie.

Hunter, passing up the meadow,
Brings me news from town,
And all day long I wonder, wonder,
If I dare go down.

The buzzard

ANN CASWELL

Jacob took his left hand from the cotton glove and looked at his finger. It was swollen all right, and it hurt; a wasp sting always did this to him. He tried to remember if he had aspirin at home. There might have been one or two left in the bottle, but he couldn't remember. At a drugstore near the edge of town he bought some, swallowed three on the way back to the truck, and then drove slowly through the shimmering mid-afternoon heat of the groves and vineyards.

Tiny globes of red fruit were appearing on the pomegranate trees bordering one side of the road; oleanders, taller than his house in the hills, and just as wide, grew on the other. Cars approaching on the straight stretch of highway seemed never to arrive. Mirage lakes pooled quietly in the heat, now in front of him, now to the left centering in a vineyard, now among the ripening melons or figs. His finger throbbed with pain and he rested his hand on his lap. What he was waiting for was the aspirin to begin to take the edge off the pain, but nothing happened.

There were no cars or trucks pulled under the umbrella trees at Cap's Corner, and he had a notion to stop for his beer now instead of later. The thought of the air-conditioned room and the shady stillness was a temptation; he slowed, almost stopped, and then saw the mosquito-abatement jeep pulling up at the edge of Cap's vineyard. The way he felt now, he was in no shape to face Guido, the bastard driver of that jeep. He couldn't even think of his burned-out face without remembering the gardenias. Even now, the browned edges of the white petals seemed more real to him than the truck or the road or himself. He felt like vomiting with the heat and the pain compressed into the swelling tip of his finger. The aspirin should have helped. He couldn't remember hurting like this before.

Weeder geese, let into the cotton fields before the rancher had gotten around to putting up the low chicken wire fencing, waddled

out into the road, and Jacob had to stop the truck three times before he reached the turn-off to the dump. The geese moved slowly across the hot pavement, their beaks open and their eyes half-shut. Dust lay along their backs and swirled up around them as they padded onto the shoulder of the road. He suffered with them, running his tongue along his crusted lips; his legs encased in the armor of sweat-stiff levis.

The trouble with this part of the valley, and he had told Banks this over and over and over, was the feeling it gave you of being caught in an airless trap, shut in on the east by dry rocky foothills and on the west by the groves. The highest growing things for miles and miles were the tall palms that could be seen pushing upward here and there, or growing in a sudden straight line from nowhere to nowhere. Jacob could not understand people who would choose to live in the valley like lizards on a flat rock.

Even the river ran tepid, shallowing out into long curves broken by sand bars or flood debris piled against trees and building out like dikes. The same river, up above, where he lived, ran brown only when there was heavy rain in the high country—and it was cold water, pooling into deep eddies, spilling over smooth marble rocks worn away into dark caves beneath the water line. He spent a lot of time near the river, or in it. With a face mask there was no end to what you could find. Old man Banks had been welcome to come up and fish or loaf around with him whenever he wanted to, but he never had. He said he liked the city when he could get away from work at the dump. That wasn't all he liked, and Jacob knew it as well as anybody, but he was a good friend.

"What new and interesting fact of life did you find in that fool river today, Jacob?" he would ask.

And Jacob would tell him even though he knew Banks didn't really care and only asked because he had a curious nature.

At the entrance to the dump now, Jacob came to a full stop, shifted, and steered carefully past the deepest chuck-holes; the load in the back banged against the heavy sides and cans spilled over the edge. The place seemed completely deserted. Dust devils whirled across desolate acres, lifting the tarpaper Banks had tacked on the roof of his shack, frightening a white leghorn off the remains of the chicken coop. Against his will, Jacob saw again on

the door of the shack, the round wire frame like the skeleton of something very lovely that had been stripped bare by desert winds. He looked away.

Cull oranges made two tall mountains and the wheels of his truck pulverized the scattered fruit. He had to stop so many times because of the road, that he finally just took off across the alkali flat and, steering around old washing machines and overturned ice boxes and piles of rubberless tires, reached the dumping area. There was no one to stop him from doing this now.

Maneuvering the truck as near the edge of the hole as he could, he opened the door, leaned out to check his position, and then let the whole load slide off without worrying about its falling exactly right. There was no noticeable difference actually, and no wasted time jockeying into impossible positions for the benefit of Banks' skeptical eyes. Dust and the ash of many burnings rose as always in a black cloud; wasps surged out of an overturned crate near the rear wheels; a field mouse scrambled into the shelter of tumbleweed piled in a corner of the barbed wire fencing.

Jacob let the bed of the truck down and slammed the door. He couldn't wait to get out of here now. His whole left arm shook with pain, and it was so hot there seemed to be the smell of burned flesh in the air. Buzzards that Banks had been known to shoot for the hell of it, wheeled over the deserted shack.

"They're the same as us, Jacob. Why not shoot them?"

The tarpaper on the roof was still flapping although Jacob felt no wind. A truck passing on the county road backfired and it was enough to make him sick. Everything was Banks and his rifle and the bleeding buzzard caught in the barbed-wire. Everything that wasn't ashes was dust soon enough.

He had taken the buzzard home with him. Oh, yes, he had. First, he had smashed Banks in the face and then he had picked up his rifle and thrown it into the hole. While Banks, speechless, retrieved the rifle from the still-smoking pit, Jacob had come up behind the buzzard and, seeing how young it was and how limply it hung from the barbs, he had just taken it up and put it into a wet gunnysack and brought it home to the hills.

He thought Banks would be an enemy ever after, but the older

man wouldn't let it go at that. "What's the old boy doing today?" he would ask.

"Growing." The way that bird would come running across the floor when he opened the door, his clipped wings trailing for balance, his mouth opened for the canned dog food, or hamburger, or whatever Jacob had brought. It was a lot of trouble to raise and couldn't fly as well as the other buzzards when he finally let it loose, but he could sit on the cool edge of the little swamp behind his place and see the strange rocking flight of his own bird, could recognize it among all the others. It was something to see him, wings ribbed in the sunlight, drop from his roost in the shallow-rooted eucalyptus and, flattening into a long glide, make circling passes over Jacob's head before landing on the porch railing. Jacob had only to close his eyes anywhere, and he could see that flight, and the red on his head and the vulture-like twist of his neck, which were not ugly things to him, and never had been, not even hanging from the wire or fouling himself in fear of the man and the wet gunnysacking.

Now he turned onto the county road and drove as fast as he could. A buzzard shadow was on the road before him; dust devils spurted up from the cotton fields; the geese clattered around a man bending over to set up the siphons for irrigation. At Cap's Corner, he pulled the truck up under the trees and sat there shaking. It took him a long time to decide to get out of the truck, and a longer time to walk the short distance from the truck to the door of the cafe. The door itself was heavy to open, and he stood leaning against it for a moment, gulping the freshness of the air-conditioned room. They yelled at him to shut the door and come in.

"Well, here he is now, and where's the ladder, Jacob?" Cap stood behind the counter, hands on his hips. Jacob smiled, but didn't speak. Sometimes he said, The ladder is with the Lord. Or, Come up to the place and see. But most of the time he just smiled.

"You all right?"

"Yeah. Just hot; open a beer, will you?" The sweat seemed to be freezing between his shoulder blades now, and he knew that if he looked in the tilted mirror above the refrigerator, he would see a great chunk of ice ripping through the softness of his shirt. He

leaned forward until his chest touched the counter edge, his hands placed on either side of him for balance.

"Too bad about Banks, huh? He caused a lot of trouble around here plenty of times, but that's a hell of a way to go—"

Jacob put his hand on the can of beer that was placed on the counter directly in front of him. He couldn't lift it. It was too cold. Even inches from the can, his hand seemed to grow purple and stiff from the cold.

"You sick, Jacob? Or did you make a few stops before here today?"

"I'm all right."

"You want to go in the back and rest for a while?"

He shook his head. The rancher on the far side of the room got up and came over to him as though he wanted to help but didn't know how. Jacob just sat there with the sweat standing out all over his face as though he were outside now on the alkali with no tree, no bush, no shade of Banks' shack anywhere in sight.

"Why don't you go in the back; I'll call you in a half hour."

"I said, No."

Cap shrugged and went on with his work, making circles with a damp cloth all down the length of the dry counter top. Jacob watched him.

"You see the wreath Guido's wife made for the old man?"

"Oh, yes. I did see it. Twice," Jacob said. "Gardenias are a very beautiful flower that you cannot touch, or they turn brown around the edges and the petals curve under like they hated you and wanted to get away from you. But the browner they get, the sweeter they smell, do you know that? It takes a sweet sweet smell to hide the smell of some things—" He looked up in time to see the glance that passed over his head from one man to the other. 'So I talk too much."

"No, go on. You don't talk too much, but make it more plain. For the sake of the peasants."

"Go to hell."

"What's the matter with you today, Jacob?"

"I talk too much."

"Drink your beer and forget it. I thought you were Banks' friend."

"Nobody was his friend. Not anybody was his friend." He drank some of the beer, and then held the can against his suddenly hot forehead. It was no good. The can was already as hot as his hand. He rested his head on the counter and closed his eyes.

They helped him into the back room and let him lie down on the couch. He seemed to breathe easier, but immediately grew more cold. This cold-hot business irritated him and when they left him alone, he turned this way and that way trying to get away from it.

Banks had burned to death. A cigarette and a hotel mattress and no more Banks. It was a great disappointment to a lot of people that he had died from something anyone could have died from. Jacob, lying in the ice of his sweat, wondered if Banks had felt the heat. Maybe he had been drinking. He liked to drink, all right. And heat never had bothered him. He didn't even sweat. Not in the heat that hit 118 more than once during the summer.

"The trouble with you is, you fight it. Give in. Relax. There's no river to jump into down here, Jacob. Just sun and dust and hot shadow. Sit down in it and have a beer before you go back to your river."

And Jacob would have a beer with him, but it didn't stay cold long enough to count three, and his throat felt seared as though he had been drinking boiling water.

No, heat wouldn't bother Banks until the very end. Maybe another man would have awakened in time. Jacob thought about that for long minutes. He thought of his own place at night, too, where the slightest breeze would rattle the dry leaves of the buckeyes growing on the hillside or cause the limbs of the young oaks to rub together, and the movement would make you feel better and give you the moment to look forward to when it would break through the small-meshed screen on the windows and touch you as you lay on the bed.

"It takes a special kind of carrion-people to live here," Banks would laugh, watching him drown in his own sweat. "Like me and like her," nodding toward the woman approaching the dump from the west. She was too old to walk barefoot in the wet furrows like a child, and she was dirty. Jacob had never seen her without dust in her black hair and dirt on her neck. And her elbows re-

minded him of the skin of a lizard. And her eyes, he closed his own to remember, were the color of slate. Her mouth lied, he knew that, but he didn't know about her eyes. He wasn't sure. She was so dirty, he knew that even if he sat and looked at her eyes steadily from now until the day of reckoning, he would not change in his feeling that no amount of swimming or bathing would make her skin less lizard-like, or her lips less cracked and dry. Once even, her lips had split right open and bled, but she had held a wet handkerchief to her mouth and come across the fields anyway. He wondered where she had learned to make a wreath of gardenias on a wire-hanger frame, and what Guido thought about it.

At home sometimes he would think about her coming up behind Banks sitting in front of the shack and just standing there with her long arms around his neck and her cheek against his gray hair. That was when Jacob had first noticed that he could not understand her eyes; especially when she talked, he could not understand them. But most of the time at home there was the soft rustling security of the possums or the coons or the skunks moving around in the darkness, and he didn't think beyond them. Or there would be quail calling from the swamp—one thing about quail, and the mourning doves, too, once you learned their call you could get them to answer you anytime at all. Sometimes he would sit up in bed and call out the window to them, and they would answer, coming closer and closer as he lowered his voice; a few times coming right up beneath the window. And finally each night there would be the sound he most looked forward to, the sharp clunk of the buzzard landing on the corrugated tin of the roof.

In the early morning when he went up the hill to get water, the buzzard would swoop down on him and sit on the edge of the flume watching him trail the buckets out on a length of rope and haul them back full of the sweet clear water.

"Jacob. Jacob, you want to get up? You feel all right? You want a beer and go home now?"

He sat up and thought about the buzzard and felt thousands of dry long years away from him, and at the same time as near to him as he was to the can of beer Cap thrust into his hand.

It was raining in the high country. As soon as the truck was out of the low hills and the lemon groves, he could see dun-colored clouds all across the tops of the brown foothills, separating them from the mountains. Although he was in sunlight, he could see the flash of lightning and hear, above the sound of the engine, the heavy thunder noise. He turned off the road just south of his place and parked out in back. Bush lupine, their seed pods hanging in the still air, grew thickly among the great boulders. Wild grapevines swarmed up the trunks of the trees in the swamp. Currant and blackberry bushes grew in dense patches, and, on the far side, up the hill in the shade of the flume, a young doe rolled under the fence and disappeared behind a rocky outcropping.

As he climbed down from the truck, Jacob cradled his aching arm against his stomach, and the pain seemed to shoot right through his body, striking his spine. He doubled over with the force of it and then vomited the small amount of beer he had been able to drink.

Lightning forked westward from the cloud, losing itself in the bright sunlight; thunder roaring down the canyon was like a freight train passing over a trestle under which Jacob was standing. Even the ground seemed to shake and, in the stillness after, pollen from the eucalyptus misted down upon him. He sneezed miserably three times and tried to hurry toward the house.

The whole thing was wrong. It should be raining here like it was in the mountains but the stupid sun just went on and on and on. He slammed the front door behind him as though he were shutting something outside, but then he had to open it again in the hope of a wind blowing off the mountains. He walked across the claw-marked floor of the room and let himself down on the bed. As soon as he could, he undressed and lay naked, as hot as though he had never left the valley. Flash, roar; flash, roar; with no let-up at all. No wind. No rain. No cloud over him. Just sunlight and thunder and lightning. It was all wrong.

He couldn't hear quail call for the noise of the thunder; the small animals would not move in this heat. The deer, the doves, nothing would help now, and he was so sick, it really mattered. It was not right for the tight little airless trap to be here, too. Finally though there was a spattering of rain on the tin roof and

through the window came a smell of sweetness from the swamp, a smell of rankness from the brown grass on the hills, a steaming smell of dampened dust. Then the rain stopped. A small wind rose, swept through the house, and fell.

The flash and roar began again, but in the distance; finally there was the roaring without the flashing, and then silence.

Jacob seemed to smell the carrion smell of the buzzard and he stared at the ceiling, waiting for the sound of claws on tin. He looked out the window. The hills were amber under the setting sun, and over the stubble a flat shadow, a silent blackness, moved across the flume, the wild grapes, the rocks, the hill. The buzzard was back, thank God. "One, two, three," he counted the circles he could not see, "four, five, six, seven." Again, the blackness on stubble, on flume, on grape, on rock, on hill. Jacob carefully closed his eyes. Beneath his head, the pillow felt as hard as a small stone. He waited for the sound of the buzzard striking the roof.

SONNET FOR CHRISTMAS

By Albert Howard Carter

At the still center of the year, the Child and we
And season waiting to be born, the roomless inn
Seems somehow, through some faithful act, to be
A reasonable, happy place for us to begin.
And was there hope? a stable steamy with breath
Of symbolic cattle, foretelling perhaps the ride
Of triumph unquote to Jerusalem, garden, and death
On the somehow available ass, somehow glorified?
Or was it love, stopping at no earthly danger,
Aware, possibly, of an antagonistic Davidic clan
In David's city, to come to be and being in a manger,
Hiding the God in a little, little man?
    Surely, such faith, such hope, such love, still say
    That love may be, was, and is the way.

The state university and religion

EDWARD J. MACHLE

The modern university traces its ancestry back to the middle ages, when theology was queen of the sciences. It could hardly have been otherwise in a day when it was clear to everyone that the things of God were the most worthy of all objects of study. History, however, has changed many things. Theology was first dethroned and then all but disowned, and the rise of the state university appeared to add legal barriers to the other obstacles to its return. The question of the place of religion in the university has been sporadically discussed for centuries, but the tempo of discussion has been so much livelier through the ten years since the publication of Sir Walter Moberly's *The Crisis in the University* (London, 1949), and the progress made so slight, that it seems high time the problem were brought out of the academic circle more effectively and laid again before the general literate public.

The problem as to whether the state university adequately recognizes religion or whether it has found a proper place for the study of religion in its curriculum has been largely discussed, by both sides this past decade, on the basis of fears. Some have feared that without religion, or at least some knowledge of religion, our system of values would wither and die and our fragmented curriculum would have no unifying principle. Others have feared that any further shred of religion admitted into the university would turn out to be but the nose of a very insistent, closed-minded, ecclesiastical camel.

Whether recognizing a superior weight on one side of the argument or responding to more concrete responsibilities, university administrators have been casting about for the best way to handle religious additions to the curriculum. They find that steps have already been taken at some schools. The University of Iowa has one such exhibit—a school of religion, established twenty years ago, wherein professors whose salaries are paid by the churches or groups of churches whose views they represent teach regular

courses in the history and beliefs of their various traditions. At the University of Indiana there is another pattern: the churches support a non-credit school of religion next to the campus; its staff also teaches academic courses on the campus. The University of Illinois has worked out an arrangement for courses taught by the denominational campus chaplains. Michigan pieces together a religion curriculum out of scattered courses in various departments. The universities of Oregon and North Carolina have long had departments of religion outside any denominational auspices. The discussion, however, still continues, even at the universities where these plans operate. There is still disagreement about the how; there is still disagreement about the why.

One of the causes of confusion in these discussions has been a failure to distinguish between two quite different questions, namely, (1) how should the state university be related to religion, viewed as a subject matter, and (2) how should the state university be related to the churches, as institutions. To divide the problem in this way is not to suggest any divorce between religion and the churches. Not a divorce, but a distinction, is needed here, since it is *church* and state, not religion and state, whose separation concerns the state university. To the extent that the study of religion can be separated from its corporate exercise, a university can teach religion without becoming in any way a religious institution. To the extent that a religion cannot be studied apart from participation in that religion's institutions, a state university cannot teach religion. Unless we can distinguish clearly enough between religion and the churches, within which religion lives, to have a basis for clear-cut administrative separation of what the university teaches from what the churches teach, we cannot have religious subject matter in the state university.

The relation between a state university and religion as subject matter depends on the nature of a state university. First of all, it is a community of scholars and teachers. It must be emphasized however that it is a professional community, engaged in a moral task. A profession is characterized by being autonomous in determining its standards and duties. The standards of the legal pro-

fession are normally decided within the community of lawyers and judges, and those of the medical profession by the members of the profession itself. Similarly the character of any university is to be judged in terms of the standards which emerge from the moral concerns, insights, and judgments of the members of the academic profession. Experience has shown that a university can maintain its honesty only as it preserves its freedom to determine its own standards and to judge itself by them.

This need for autonomy poses some real difficulties for the state university. Just as separation of church and state frees the church from being an arm of the state and allows it to be more faithful to its calling, so something akin to "separation of university and state" is necessary in practice, if a state university is to be free really to be a university. If public opinion, the state legislature, or even the board of regents should require the university to teach what the professional academic community believes it should not or to abstain from teaching what it sees clearly to be its moral responsibility to teach, the university is not merely being changed. It is being destroyed, as the German universities discovered under Hitler.

For the academic community to be moral, however, autonomy is not enough. It must also have commitments. It is often pointed out that "everyone, whether he admits it or not, has his own orthodoxy"—and the orthodoxy of the university must lie in those principles which undergird and secure the most open investigation, the freest meeting of informed minds, and the most public presentation of evidences and grounds for belief. The university cannot be a mere hodgepodge exhibit of a multitude of unconnected intellectual traditions; it must be committed to basic rules as to how questions are to be answered and disagreements ironed out. There are religious traditions, for instance, which refuse to listen to other views or to subject their own tenets to earnest and searching criticism. Excluding these from representation in the university is not at all improper. They bar themselves from participation in the university family by their implicit denial of the worth of the whole university enterprise. The university may have a responsibility to investigate such traditions, to narrate their history, record their tenets and list their statistics; it cannot con-

sider them to be part of the cultural tradition which it must preserve, clarify, enlarge, and transmit, since they contradict the moral nature of the university, no matter how wholesome their other mores may be.

In short, the university must represent as it were an intellectual public-at-large—perhaps an ideal one but an ideal public not too dissimilar from the effective bearers of our cultural traditions. This means it must operate within the languages and conventions of broadest acceptance in the intellectual community, even when criticizing them. Anything narrower than this belies the universality of the university. A Marxist university in Russia might be no anomaly; a Marxist institution here could not be a university, since it could not properly speak for the culture nor effectively to it. Its commitments would be far too narrow to allow the full scope of intercourse and revision our very complex background requires.

To be true to its moral character, then, a university, and especially a state university, must always take as basic what it judges to be the least-common-denominator presuppositions of the culture. Hence, it *cannot* teach theology. Theology proper, as distinguished from the philosophy of religion or "natural theology," always affirms a particular revelation, not reducible to generally available or publicly corrigible sources of knowledge. Such an affirmation is seriously advanced only as a tenet of some particular group or church, and must assert its independence of "ordinary human reason." As theology, it must assume the claim to be granted. The university, however, must treat such a claim as only one among many, all to be evaluated according to the academic community's general principles. What is necessarily theology in the church can thus be only philosophy of religion in the university. Conversely, for the university to teach theology in any church's terms is to sacrifice its particular synoptic function in the transmission of culture to its being an instrument of a church or set of churches, which are institutions of quite a different sort. After all, education and the perpetuation of culture are functions of many different institutions; the university is bound only to fulfilling its peculiar role in this regard.

In any culture, then, where religions are plural, wherein reason-

able men converse on bases not identifiable with those of any one religion, *a state university must be a secular institution,* whether church and state be separated or not. It must deal with sacred things with no greater reverence than it deals with other rich phenomena of the human enterprise—the arts, for instance. Those who cry "Shame!" at this are simply not facing up to the fact that our religious traditions themselves sometimes have to fall back on such "secular" bases of conversation in order to communicate clearly with one another.

Jefferson's famous chapel at the University of Virginia, often claimed as evidence against the case for the secular university in our society, is really quite in line with the above argument. Jefferson was a deist, and the affirmations of deism—that God created the world, that He demands morality of men, and that He rewards the good and punishes the evil in an afterlife—were a common denominator for the educated men of the time. All disciplines could be discussed on its basis, and upon it all particular theological systems could be erected. Deism was the public background for discussion of "educating the whole man."

How different our situation is is well shown by the reaction of two of my colleagues to a paper read by a local chaplain. The paper suggested a place for religion as an integrating element in education. Said they, "Does he really think that you can't give the whole man a secular education?" This poses the problem very nicely. We now have a culture, academically a very busy and responsible culture, which is thoroughly fragmented as to its answer to the question *what man is.* The university cannot define its program in terms of any special pleading in behalf of a view of man specifically held only within this or that tradition in our culture. It must still, however, decide what the whole man is, and its program regarding the teaching of religion must reflect this decision. To be true to its cultural heritage, it *must* teach religion—it already does in a thousand ways in dozens of subjects—but it must do it in the light of its own moral perspectives. It cannot, in honesty, be the representative of any church or group of churches, no matter how inclusive it makes such representation.

For example, when I teach my course on the development of Christian thought, it is taught by an evangelical Protestant. Ob-

jectivity requires that I acknowledge this about myself, and there is nothing about the university that would make this a basis for my disqualification as a teacher. It would be otherwise, however, if I were teaching the course *as a representative* of evangelical Protestantism. In that case, a serious change of conviction, even if brought about by the results of my researches, would call my place in the university into question, even though I had been doing what it is the business of a faculty member to do, namely, to think critically and to change his mind if that be indicated.

Acceptability to a particular church cannot be any part of the university's requirements for a teacher of religion. Such a teacher should be an active participant in some religious body, of course, just as a teacher of art or music must constantly participate in those fields, but even this requirement is always to be put in the university's terms, not those of a church. It is this sort of consideration which is fatal, in the last analysis, to the Iowa plan referred to earlier, wherein ecclesiastical approval in part determines faculty status. Such approval depends on things foreign to the university's proper standards, things to which the university's workings ought not to be subordinated, even if conflicts can in practice be avoided.

Theology, then, as theology, cannot be part of the university curriculum. This is not to cast any reflections on its status as a discipline, for it can be as intellectually respectable as any. It is simply that the propositions of theology can meaningfully be discussed within the university only as historical or sociological events or as theoretical philosophical propositions. As such, they would belong with other historical and sociological events and other philosophical propositions in the disciplines and departments which already deal with such things.

Once we leave the classroom and official university functions, however, the situation is different. As remarked above, teaching as a moral activity always must be carried out upon ground common to the group being taught. This means that genuine theology, even piety, has a functioning place in the university whenever like-minded groups may gather. If a devout student with a religious

problem wishes to discuss it with a professor, there is no reason why he should not seek one who shares the student's own religious beliefs, nor any reason why the professor should talk as if their only ground for discussion is the common ground of the university generally. He ought to be quite clear, though, when he is talking theology and when history, or psychology, or philosophy. He ought also to be quite clear as to when he is speaking for his discipline generally and when as a private individual within that discipline. On the whole, these safeguards are habitually observed by professors anyway. It is much more common that the student knows so little of where his professors stand religiously that he does not know whom to go to if he is religiously puzzled.

This is one of the problems the churches hoped to be able to meet with the institution of unofficial denominational chaplains and religious facilities on the edge of the campus. To an extent this has been successful: students of the various religious traditions know there is some appropriate person to whom they can turn. The chaplains themselves, however, find they are in a quandary. Neither the churches nor the university nor they themselves have decided just what they are to be doing, or how, or quite why. Parents, and in some cases even ecclesiastical authorities, see them as extensions of the pious home or the parish church, on the campus to preserve Mary's childlike faith from the strains of questioning. The university is tempted to see them as additional "student activity leaders." They themselves are troubled by the need to represent piety to the overquestioning student and questioning to the overpious, to represent the university to the churches and the churches to the university. The university should have defined their place within its walls, but instead it has left them to discover their own areas of freedom and responsibility, subject to its most general rules and the demands and hindrances placed by their churches. Probably more important still is the fact that they have been accepted hardly at all by the academic community. Few professors know them, even fewer are concerned with their place in the university, and they are unrelated to the large mass of students outside of their denominational groups.

The dilemma of the chaplains is difficult to resolve, since they are caught between two radically different institutions. The uni-

versity is committed to search and evaluation, the church to witness and commitment. These are not in principle antithetical: search and evaluation are found in the churches, certainly, and commitment and witness in the university. In the latter, however, commitment is a relative thing within the larger context of concern with knowledge and communication. For the churches, commitment is of supreme importance. The university must treat the churches as details within its own concerns; the church must treat the university as one detail within *its* concerns. Where each insists on preserving its own soul in purity, insisting that intercourse can be only in *its* terms, anyone asked to work astraddle the gulf between them is at least uncomfortable and may even be immobilized.

Here the situation seems to rest in most state universities. A certain larger number of course offerings in the fields of religion are appearing each year, sponsored with varying degrees of responsibility but little clarification of principle. The academic community, especially the faculties, show a diffidence toward discussing the question. The chaplains, as those most directly concerned, earnestly wrestle despite their suspicion that no one else is watching. And many of us who are concerned about the problems fear that no progress will be made until the church community generally faces up to one necessary condition of a breakthrough: a deep recognition of the real sanctity of the secular pieties. The whole man cannot belong to God if God belongs to someone.

authors

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